Appendix A:
General Description and Photographs of Collaroy-Narrabeen Beach and Fishermans Beach

CONTENTS

A1. HISTORICAL SETTING

A1.1 General Background

1.1.1 Aboriginal Settlement

Before European settlement, the Guringai people occupied a vast area from Newcastle through to southern Sydney. At the time of European settlement the northern beaches was the traditional home of the Guringai people (Warringah Council, 2013). The Guringai lived in large groups throughout the region because it was so rich in food supplies such as fruit, nuts, seeds, leaves, roots, bulbs, honey, nectar, insect grubs and fish (National Surfing Reserves, 2013).

1.1.2 Collaroy–Narrabeen Beach

The first European settlement of the Collaroy-Narrabeen area was in the early 1800's (Public Works Department [PWD], 1987). In particular, the first land grants in the Collaroy-Narrabeen Beach and Fishermans Beach area were made between 1815 and 1819 and a bridge over Narrabeen Lagoon was first opened in 1880 (Ogden, 2011).

In January 1882, the paddle steamer *SS Collaroy* ran around at the present Collaroy Beach (see **Figure A1**), eventually giving the site its name, and remained there until September 1884 (Ogden, 2011). Extensive dunal vegetation (including substantial trees) is evident in **Figure A1**, in a largely undeveloped area except for a track in the approximate present Pittwater Road location. Beach scarping due to erosion is also evident in **Figure A1** to the left of the vessel.

Figure A1: *SS Collaroy* beached at present Collaroy Beach sometime between 1882 and 1884 (from Ogden, 2011)

In 1906, land at the northern end of Narrabeen Beach was subdivided and auctioned. A view of Collaroy Beach in around 1907 is provided in Figure A2, sourced from the National Library of Australia. The general lack of substantial dune vegetation (particularly compared to **Figure A1**) and relatively low and wide sandy area is evident seaward of Pittwater Road at this time.

Figure A2: Collaroy Beach in around 1907, showing the ladies dressing shed

Steam tram services were extended to Narrabeen in 1913, and with easier transport the surrounding area (particularly Narrabeen Lagoon) became popular for holidays and camping (Ogden, 2011).

By the 1930's (Figure A3[1]), most of the Collaroy-Narrabeen beachfront south of Goodwin Street had been developed with houses and other structures including various Surf Life Saving Club (SLSC) buildings and Arlington Hall (then a theatre constructed in 1919, now Surf Rock Hotel and Collaroy Services Beach Club). However, only about half of the lots north of Goodwin Street had been developed at that time. By 1941, the Collaroy-Narrabeen beachfront had been essentially fully developed.

The seawall at the southern end of Collaroy Beach (from Collaroy Services Beach Club southwards) was constructed in the 1930's[2]. There is also a stepped concrete and vertical steel sheet pile seawall at Collaroy SLSC, constructed in the late 1960's (see **Appendix B**).

[1] Sourced from State Library of NSW PICMAN database, Frame Order No GPO 1 – 07320, NSW Government Printing Office collection of copy negatives, 1870-1988.
[2] According to Gordon (1989), this 300m long seawall is of stone gravity construction (plus a 70m long concrete wall stepped at Collaroy SLSC), with a toe level of 2.2m AHD and crest level of 3.75m AHD (reducing towards the southern end of the beach).

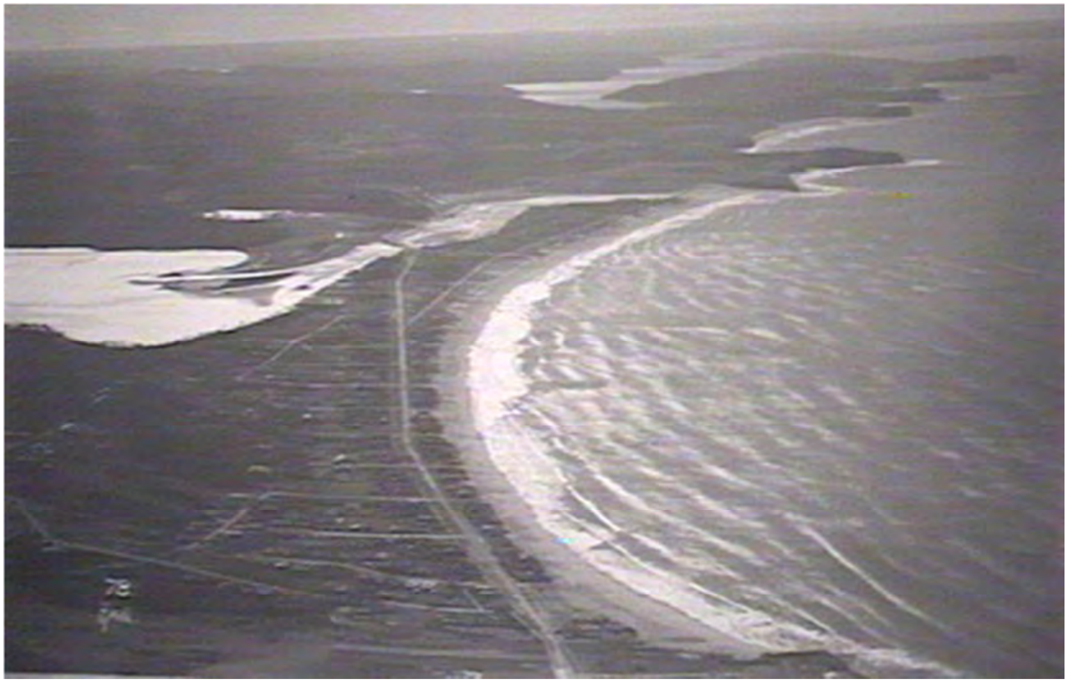

Figure A3: View of Collaroy-Narrabeen Beach in around the 1930's

The opening of the Wakehurst Parkway road in 1946, and rise in car ownership, assisted in driving a subsequent post-war building boom in the area (Ogden, 2011).

Major high rise unit blocks at Collaroy-Narrabeen Beach include "Shipmates" and "Flight Deck" (located immediately south of Ramsay Street), and "Marquesas" (twin towers located just south of Devitt Street), which were all built in the 1960's.

Short (2007) noted that the four Surf Life Saving Clubs along Collaroy-Narrabeen Beach were formed in 1912 (North Narrabeen), 1964 (Narrabeen), 1922 (South Narrabeen) and 1911 (Collaroy). Further discussion on the development of these Clubs is provided in **Appendix B**.

1.1.3 Fishermans Beach

Fishermans Beach was so-named as it had been used by fishermen since the late 1700's and was once used as a port for loading cattle for the Sydney market (Short, 2007). From 1870 to 1890 the beach was inhabited by squatters that comprised fishermen who built huts on the beach (Figure A4[3]). The habitation of the beach by squatters was challenged in court in 1917. The resulting court case determined that the squatters were allowed to stay on the beach, and the huts were still in operation during the 1930's and 1940's (Boyce, 2006). However, over time these dwellings were progressively claimed by natural processes and were mostly removed in the 1950's when fish marketing was centralised at the Fish Markets in Sydney (Darroch, 1996).

[3] Sourced from http://www.photosau.com/warringah/scripts/home.asp.

Figure A4: View of huts used by squatting fishermen in the late 1800's and early 1900's

PWD (1987) noted that most of the present residential area of the Fishermans Beach beachfront had been developed with houses by the 1930's.

Darroch (1996) reported that sand at Fishermans Beach drifted to the north and was regularly replenished by trucks dumping sand back on the beach that was originally sourced from Narrabeen Lagoon. She also noted that the area landward of Fishermans Beach was previously swamp land, and up to at least 1920 was backed by relatively high sand hills.

The seaward end (to around the low water mark) of the old boat ramp at Fishermans Beach was demolished and replaced with a new concrete slab founded on rock fill and compacted gravel in 2009. Prior to these restorative works, the ramp was suffering from extensive cracking and slumping of the slab, and voids across the ramp surface.

Patterson Britton & Partners (2008b) noted that there was sand deposition on the eastern (southern) side of the ramp and erosion on the western (northern) side, consistent with the observations of northerly drift reported by Darroch (1996). That stated, there have been times when the opposite has occurred, with sand relatively built up on the north-western side (for example, in 29 January 2011 aerial photography).

A2. PHYSICAL CHARACTERISTICS

A2.1 Topography

Ground elevations landward of Collaroy-Narrabeen Beach generally decrease moving from north to south. This is illustrated in Figure A5, Figure A6 and Figure A7, with shaded contours shown at 2m intervals seaward of Ocean Street and Pittwater Road[4].

From "Marquesas" (just south of Devitt Street) and northwards, elevations landward of dune vegetation (in development and parkland areas) were generally found to be between about 8m and 10m AHD. South from "Marquesas" to Stuart Street, corresponding elevations were generally between about 6m and 8m AHD. South from Stuart Street to Collaroy SLSC, corresponding elevations were generally between about 4m and 6m AHD. South of Collaroy SLSC, corresponding elevations were generally between about 2m and 4m AHD.

So-called "Precinct" boundaries are shown on Figure A6 and Figure A7 for reference. Historically (first adopted by Nielsen Lord Associates, 1988), the Collaroy-Narrabeen Beach and Fishermans Beach area has been divided into Precincts as follows:

- Precinct 1 at Fishermans Beach;
- Precinct 2 at Collaroy Beach south of Jenkins Street;
- Precinct 3 at Collaroy-Narrabeen Beach between Jenkins Street and Devitt Street;
- Precinct 4 at Narrabeen Beach between Devitt Street and Albert Street; and
- Precinct 5 at Narrabeen Beach north of Albert Street.

Shaded contours at 2m intervals landward of Fishermans Beach are shown in Figure A8[4]. It is evident that elevations increase to about 12m to 14m AHD at the headland between Collaroy Beach and Fishermans Beach. South of the headland, elevations sharply reduce to between 2m and 4m AHD near Fox Park. The remaining residential area north of Anzac Avenue at Fishermans Beach is generally at an elevation of between 4m and 6m AHD, with higher areas immediately north of Anzac Avenue. The area south of Anzac Avenue is also generally at an elevation between 4m and 6m AHD.

[4] Based on Airborne Laser Scanning ground elevation data derived on 15-16 March 2007 and supplied by Council.

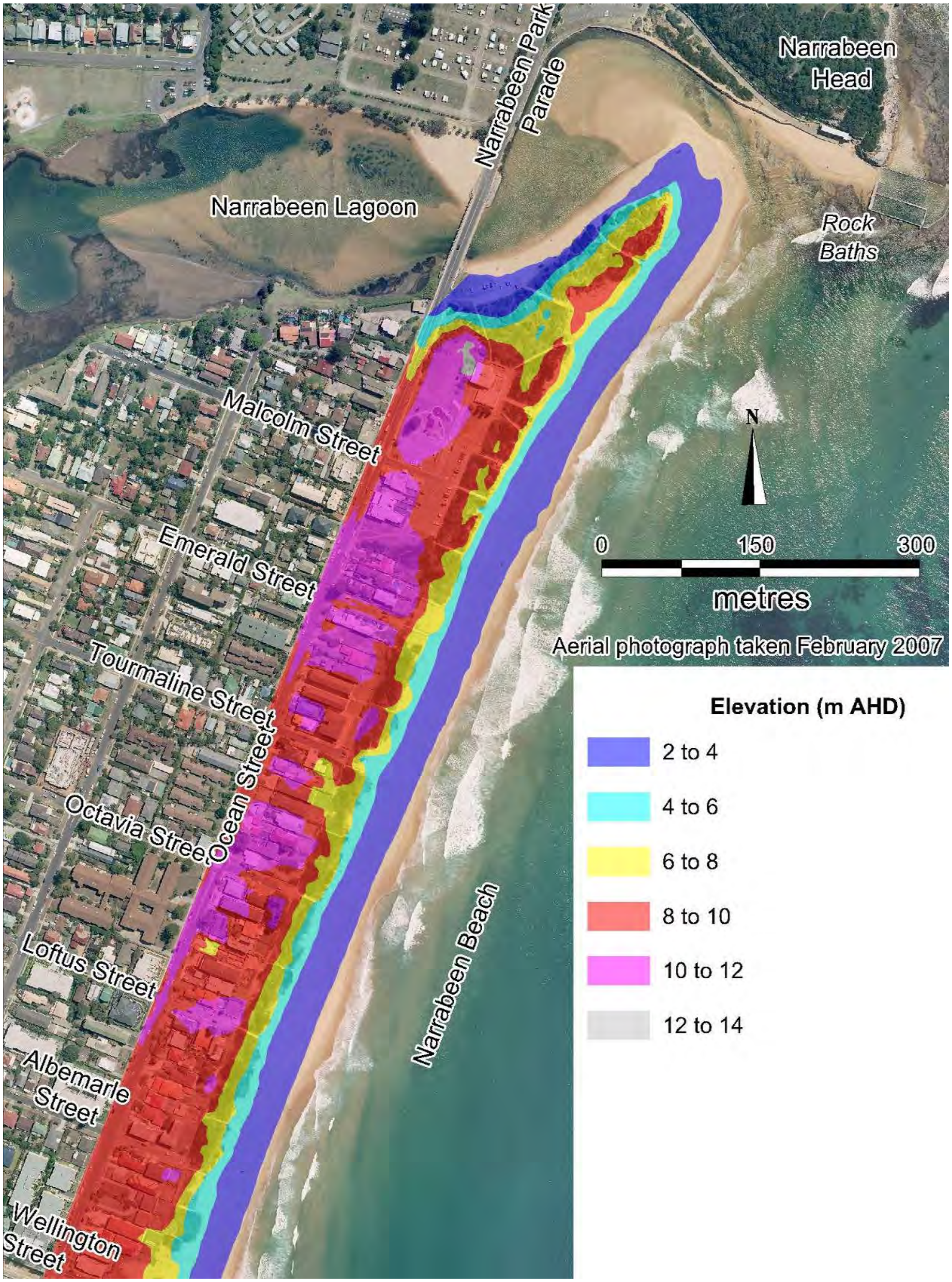

Figure A5: Shaded contours (2m interval) along northern end of Narrabeen Beach

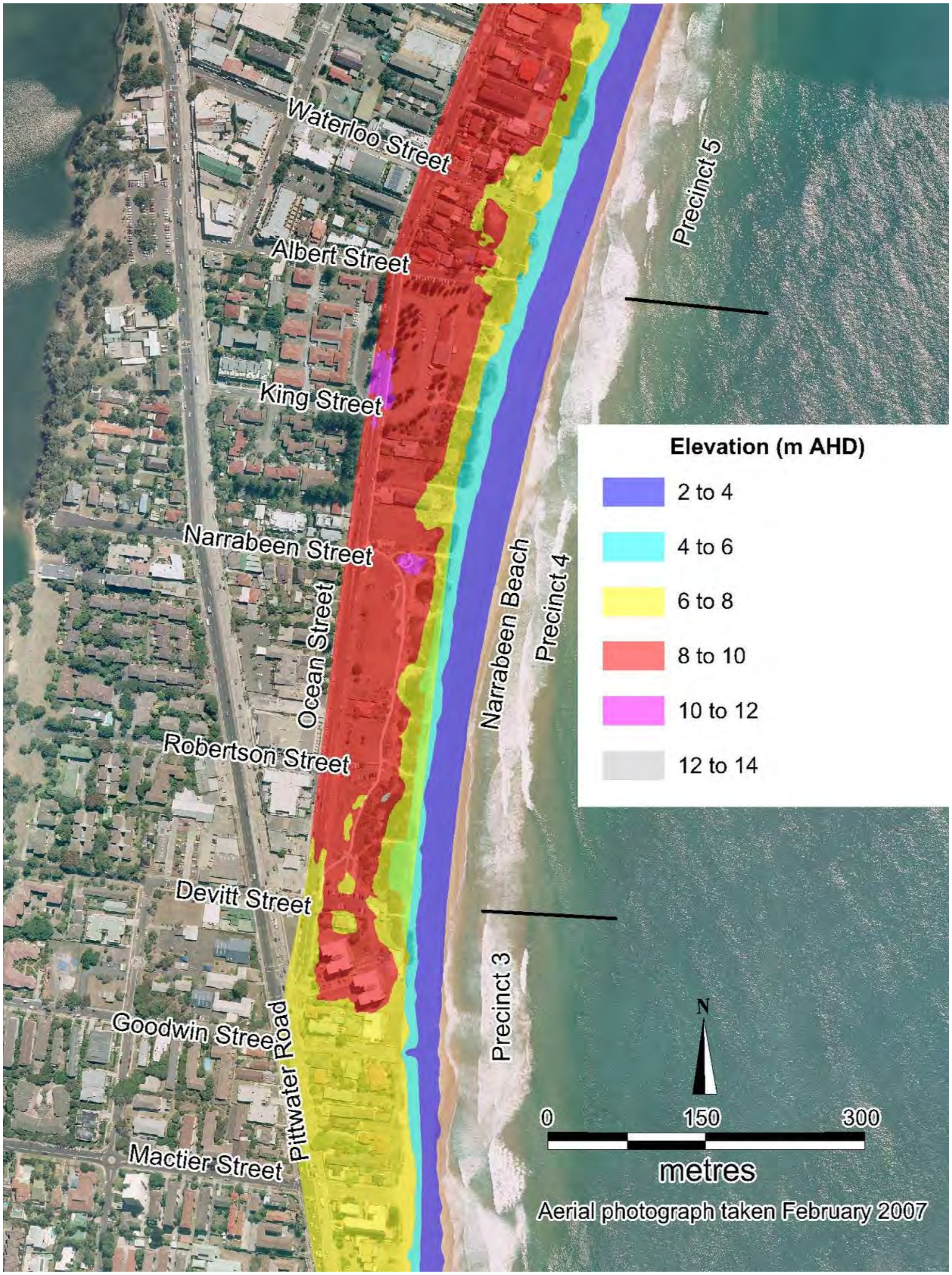

Figure A6: Shaded contours (2m interval) along southern end of Narrabeen Beach

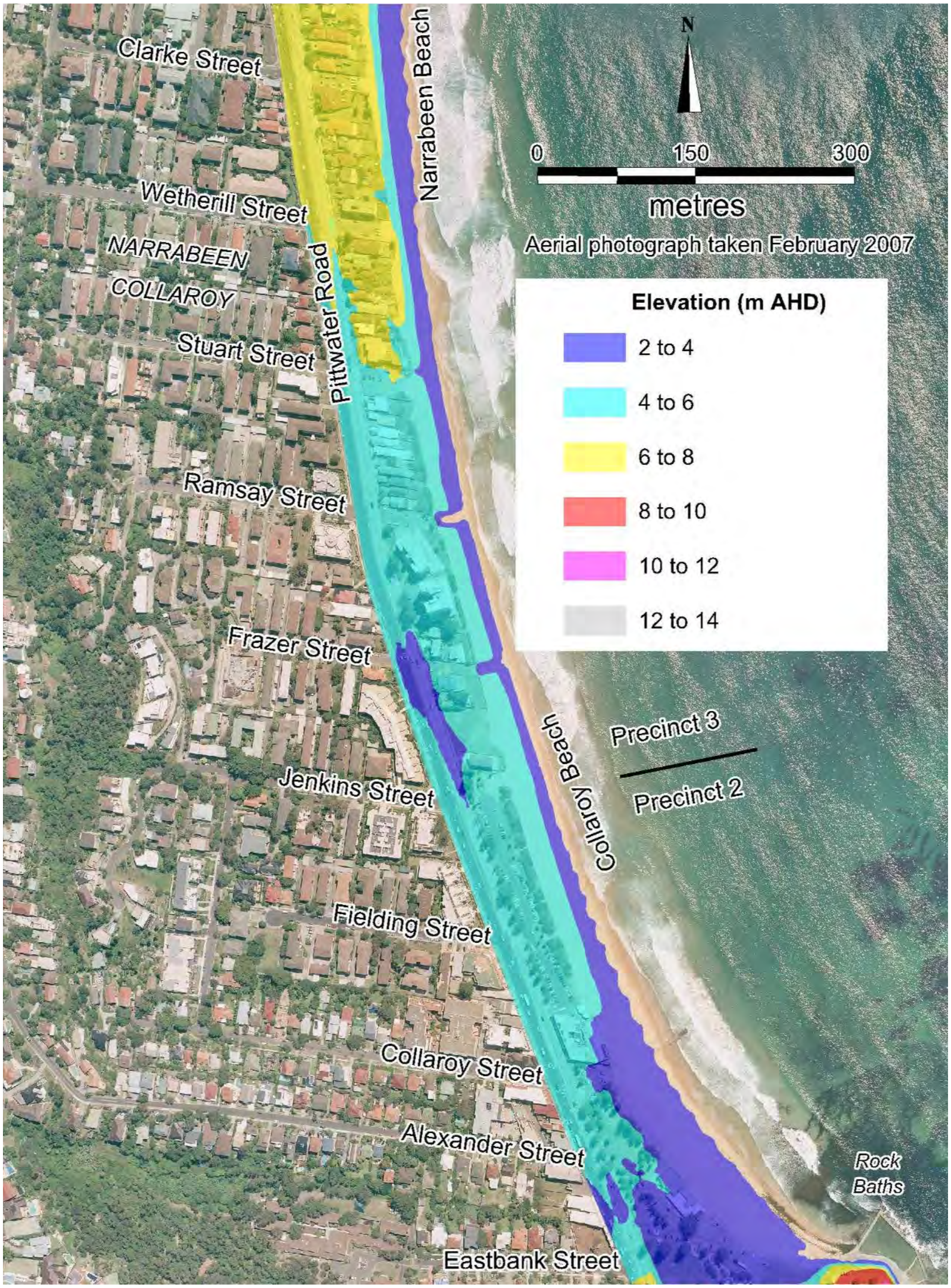

Figure A7: Shaded contours (2m interval) along southern end of Collaroy-Narrabeen Beach

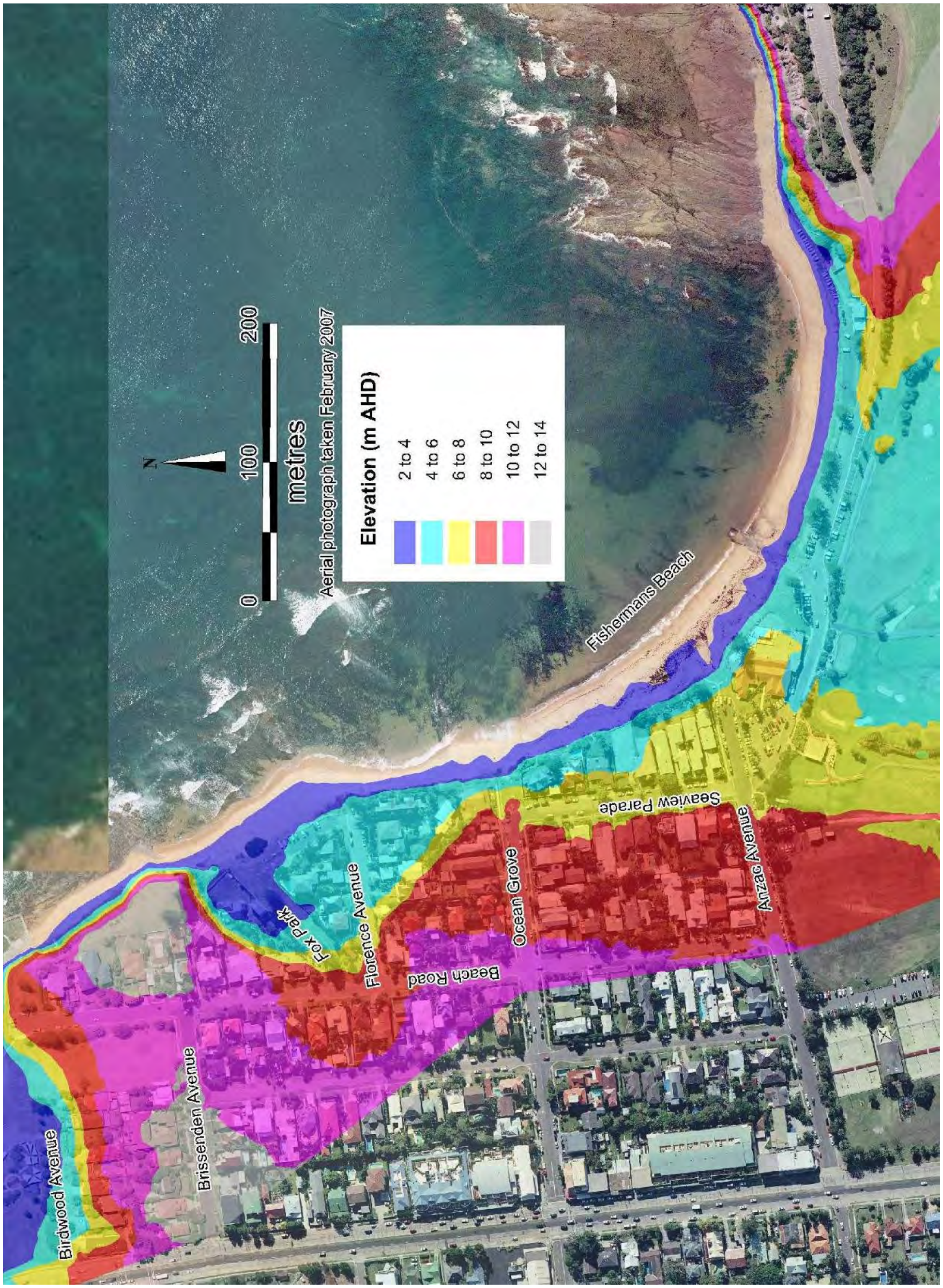

Figure A8: Shaded contours (2m interval) along Fishermans Beach

The variation in elevation along Collaroy-Narrabeen Beach and Fishermans Beach can also be illustrated by plotting the maximum elevation in each photogrammetric profile (as recorded in April 2006) versus position along the beach[5], as given in Figure A9 and Figure A10 respectively.

It is evident that the maximum dune height at the Narrabeen Lagoon entrance was about 3m AHD in April 2006. Dune heights sharply increased south of the entrance, and from 100m south of Narrabeen Lagoon entrance to Devitt Street maximum dune heights averaged about 9.4m AHD, with a minimum of 8.0m AHD and maximum of 10.9m AHD. The highest elevations in this region were between Emerald Street and Loftus Street.

South of Devitt Street, maximum elevations generally reduced steadily to about 7m AHD near Clarke Street, 6m AHD near Stuart Street, and 5m AHD near Frazer Street, before increasing to about 6m AHD between Jenkins Street and Fielding Street. South of Fielding Street, elevations reduced to about 4m AHD near Collaroy Services Beach Club.

Along Fishermans Beach, maximum elevations reduced from 13m AHD on the headland near Brissenden Avenue to 4m AHD near Fox Park. Elevations then steadily increased moving south to about 9m AHD near Ocean Grove, then reduced steadily to about 7m AHD near Long Reef Golf Club. East of the Golf club, elevations reduced further to about 5.5m AHD at the boat ramp, before increasing moving further east to about 8m AHD near the Warringah Surf Rescue building and 10m AHD near the Long Reef Fishing Club hut.

[5] Note that caution should be applied in interpreting these elevations in terms of protection of development from coastal inundation, as the positions of reported maxima may be landward of development.

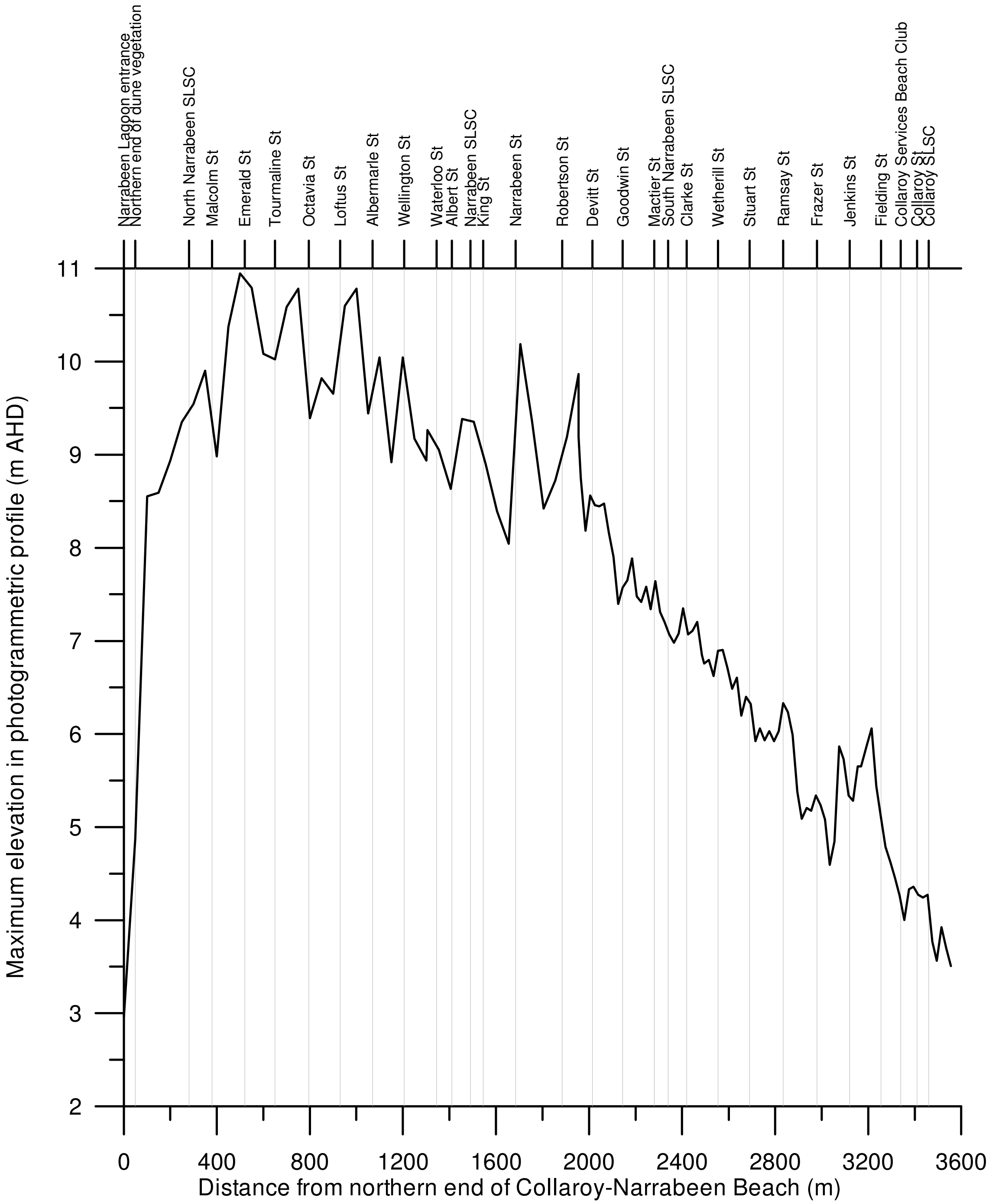

Figure A9: Variation in maximum elevation in beach profiles along Collaroy-Narrabeen Beach

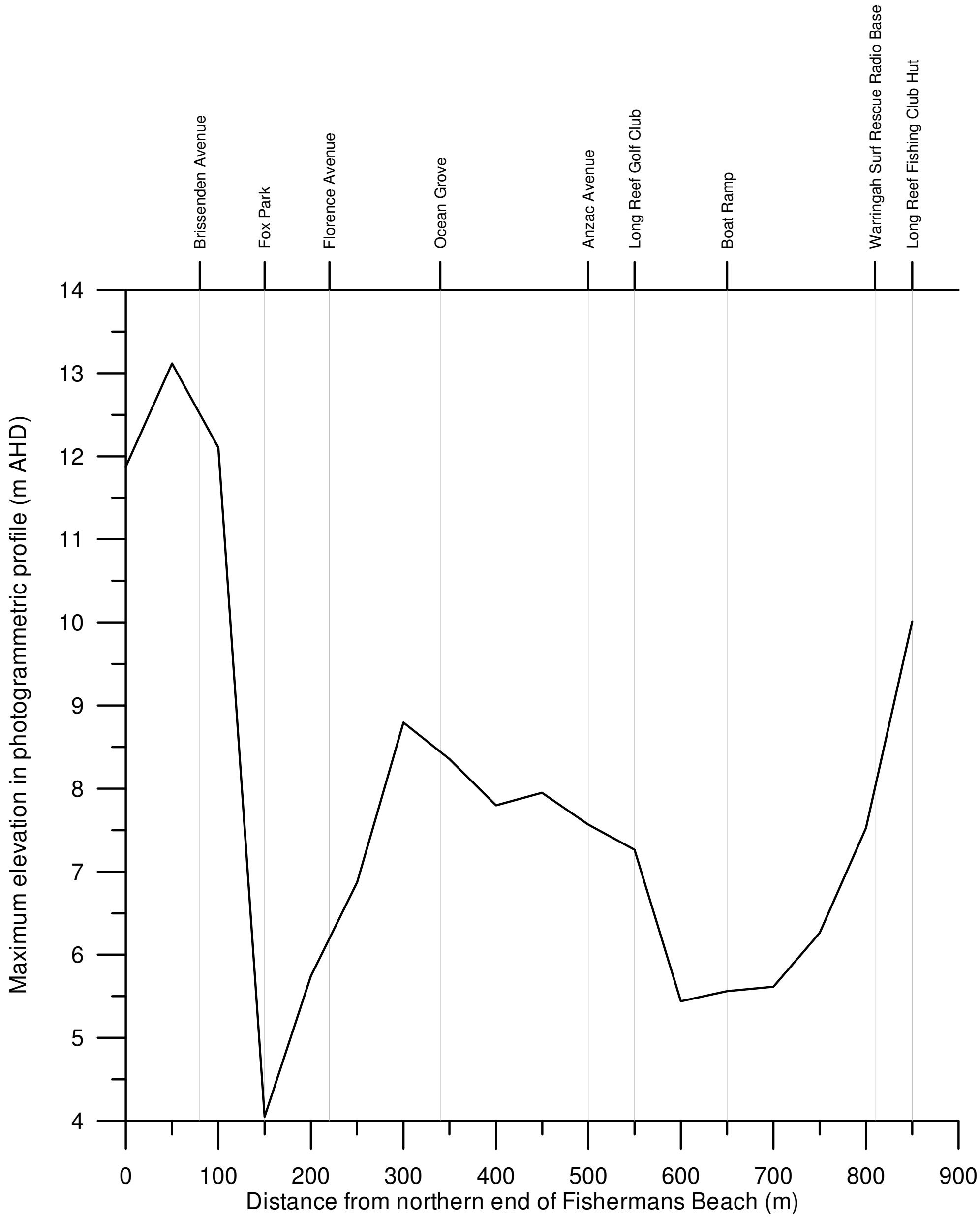

Figure A10: Variation in maximum elevation in beach profiles along Fishermans Beach

A2.2 Bathymetry and Seabed Types

Bathymetry offshore of the study area, and seabed types, are depicted in Figure A11[6]. Note that depth contours shown are relative to Indian Springs Low Water (ISLW)[7]. The key to seabed types shown in is given below:

[6] This information was derived from the Seabed Information Charts 82310-575 (Broken Bay) and 82310-576 (Sydney Heads) published by PWD in 1989, developed from surveys undertaken between 1979 and 1985.
[7] Add 0.925m to convert depths to AHD. Note that land contours in these Figures are relative to AHD.

KEY

- Medium to coarse grained, orange coloured sand with typically 40% shell.
- Very coarse grained orange coloured gravelly sand.
- Fine to medium grained, golden coloured sand, with varying shell content.
- Areas of reef partly covered by sand.
- Rock reef.
- Reef materials consisting of shell, reef and coral fragments and small amounts of sand and gravel.
- Rock shoreline.
- Sandy shoreline

It is evident that there are extensive areas of rock offshore of Long Reef Headland and the southern end of Collaroy Beach, as well as rock areas at around 20m to 30m depth moving north along Collaroy-Narrabeen Beach. Rock is also evident offshore and south of the Narrabeen Lagoon entrance.

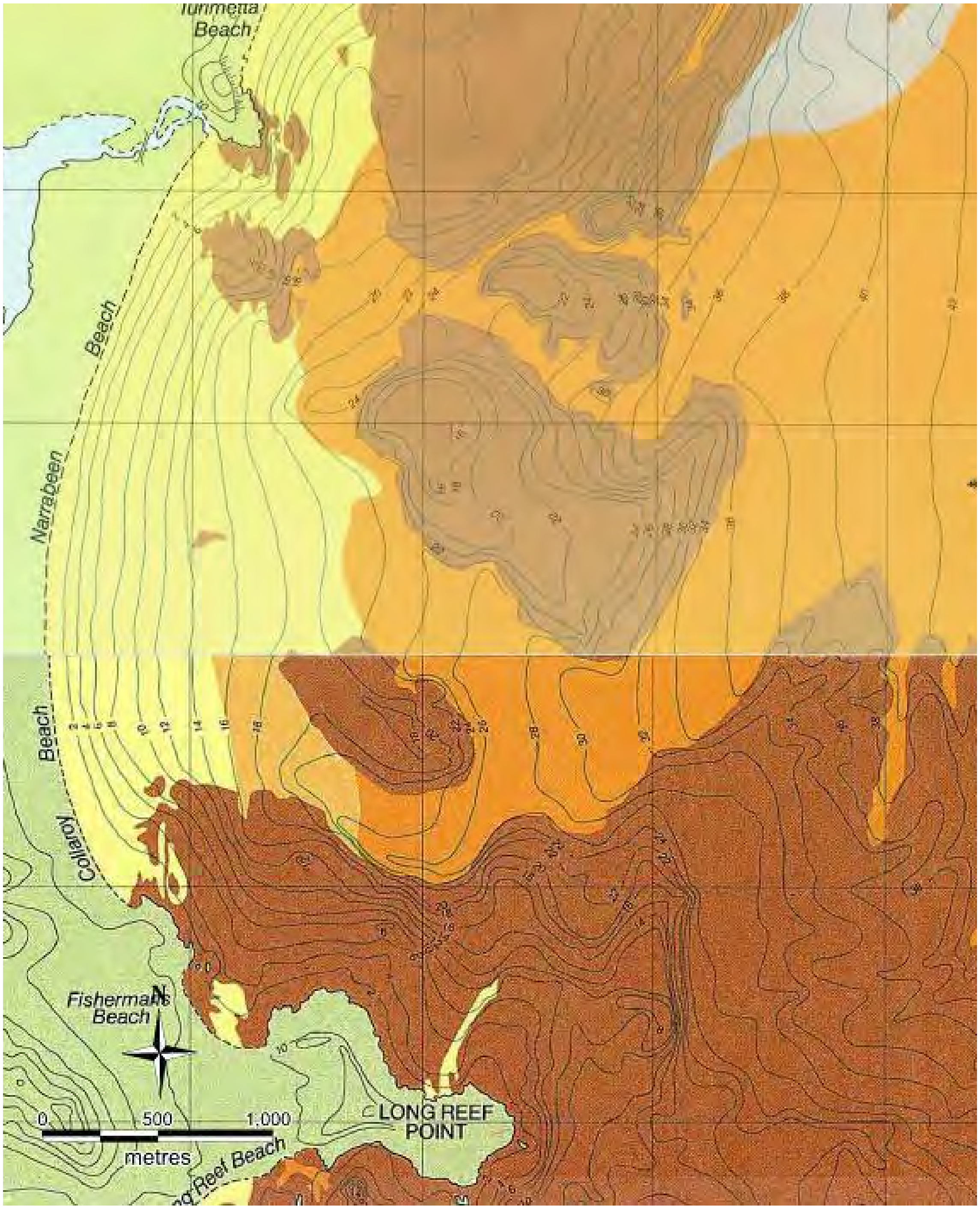

Figure A11: Bathymetry and seabed types offshore of Collaroy-Narrabeen Beach and Fishermans Beach

A2.3 Subsurface Conditions

Knowledge of subsurface conditions is important in the determination of coastline hazards relating to erosion and recession. This is because areas with inerodible subsurfaces (particularly above about 0m AHD) such as stiff clays and rock do not experience shoreline fluctuations as occur in sandy beach areas.

Subsurface conditions are also of interest with regard to foundation conditions of structures. For example, a structure founded on rock would be expected to be at significantly less risk of damage than a structure founded on sand (with conventional shallow foundations) that could be undermined.

The subsurface in the active coastal zone (above about 0m AHD) at Collaroy-Narrabeen Beach has generally been found to be sandy. For example, geotechnical investigations completed as part of the Geomarine (1991) study indicated that the subsurface in the active coastal zone at Collaroy-Narrabeen Beach was generally sandy. A total of six boreholes were drilled along the beach, with medium dense to very dense sand typically being encountered above 0m AHD. Very dense indurated sand (cemented sand) was encountered below about 1m AHD to 2m AHD at the boreholes along Narrabeen Beach.

At Fishermans Beach, conditions have been found to be more variable, with inferred sandstone bedrock refusal at around 2m AHD near Fox Park, the existence of clay materials and extremely weathered claystone in the active coastal zone near Ocean Grove, and sand near Florence Avenue.

At Fishermans Beach, Geomarine (1991) documented subsurface conditions at two boreholes. There were clay materials (hard, medium to high plasticity) between about -2m AHD to 5m AHD in a borehole that was drilled near Ocean Grove, with a layer of extremely weathered claystone at 0.5m AHD. At the other borehole (about 15m north of Florence Avenue), the subsurface was generally sandy in the active coastal zone, with extremely weathered to highly weathered claystone encountered at about -0.6m AHD.

Geotechnical investigations have also been undertaken in relation to private development along Fishermans Beach. This has included investigations at (moving north to south):

- 29 Beach Road Collaroy, located immediately north of Fox Park (Jeffery and Katauskas, 2008a), which indicated that there was inferred sandstone bedrock refusal at around 1.5m to 2m AHD at this location;
- 3 Ocean Grove Collaroy (2 lots north of Ocean Grove) by Crozier Geotechnical Consultants (2013), which indicated extremely weathered sandstone at around 1m to 2m AHD and iron rich sandstone bedrock at around 1m to 2m AHD; and
- 5 Seaview Parade Collaroy (3rd lot south of Ocean Grove) by JK Geotechnics (2012), which indicated that there were very stiff silty clays below about 2m AHD.

Jeffery and Katauskas (2008b) also completed a geotechnical investigation relating to proposed boat ramp extensions and repairs at Fishermans Beach. This included 2 boreholes and 4 Dynamic Cone Penetrometer tests on the beach, with all surface levels below 0.9m AHD. This indicated a sandy subsurface overlying claystone bedrock at about -1m AHD to -2m AHD.

A2.4 Beach Width

The cross-shore width[8] of sandy beach at Collaroy-Narrabeen Beach is typically about 50m (spatially and temporally averaged). However, beach width varies significantly in response to erosion and accretion, and also varies spatially along the beach. A plot of the mean, minimum (most eroded) and maximum (most accreted) beach widths along Collaroy-Narrabeen Beach (based on monthly surveys from 1976 to 2008) is provided in Figure A12.

It is evident that Collaroy-Narrabeen Beach is generally most narrow near Wetherill Street, which is partly related to rock protective works jutting out seawards in this area. The beach is generally widest at the northern end near Narrabeen Lagoon, in the vicinity of Narrabeen SLSC, and at the southern end near Collaroy SLSC.

A plot of variability in beach width (as defined by the difference between maximum, mean and minimum widths) versus distance along Collaroy-Narrabeen Beach is provided in Figure A13. It is evident that from Wetherill Street northwards, the maximum variation in beach width is (on average) about 45m, reducing to 34m (on average) south of Stuart Street.

[8] Measured seaward to 0m AHD from the sand/vegetation interface or seaward edge of protective works when exposed.

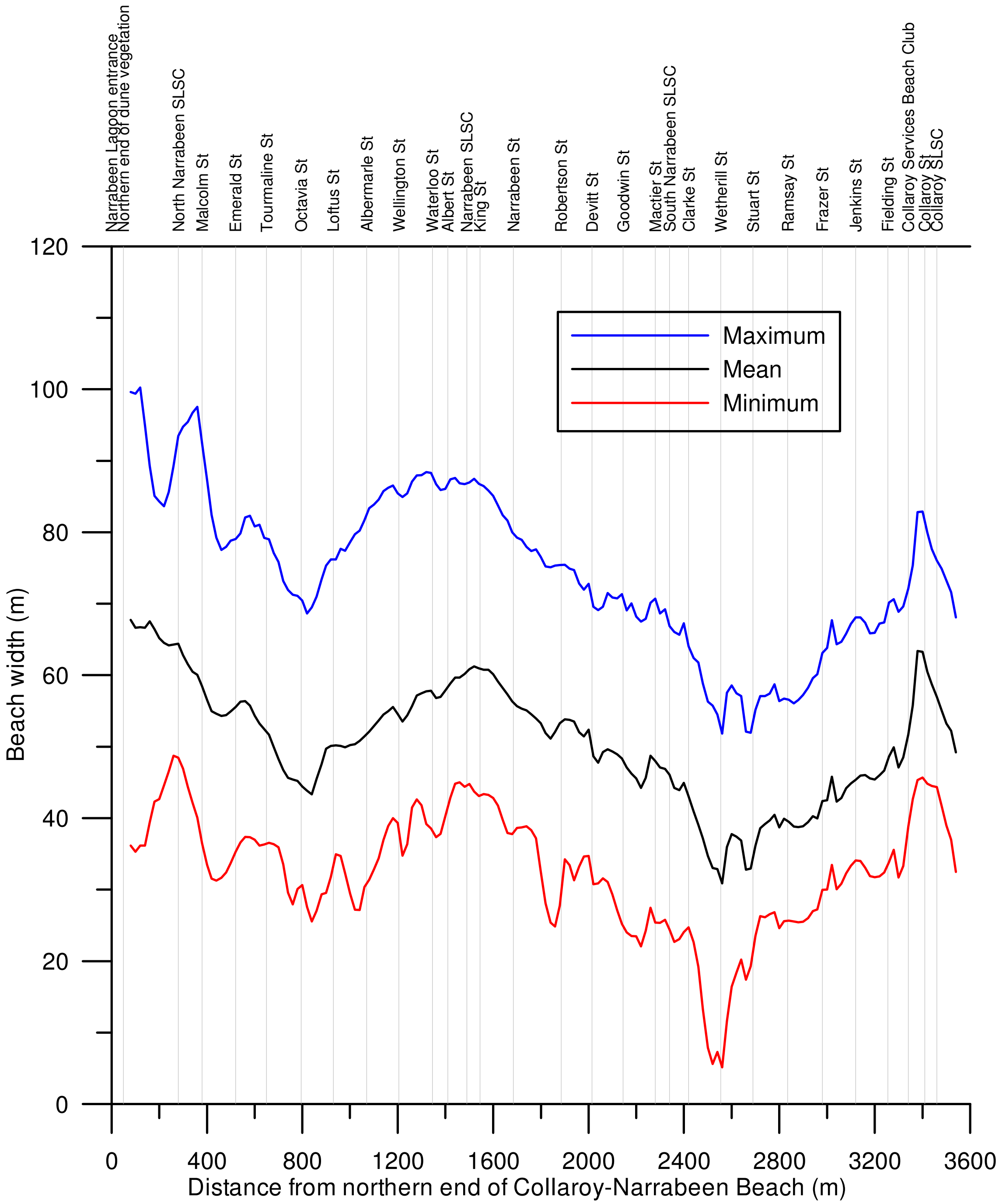

Figure A12: Mean, minimum and maximum beach width along Collaroy-Narrabeen Beach based on monthly profiles from 1976 to 2008

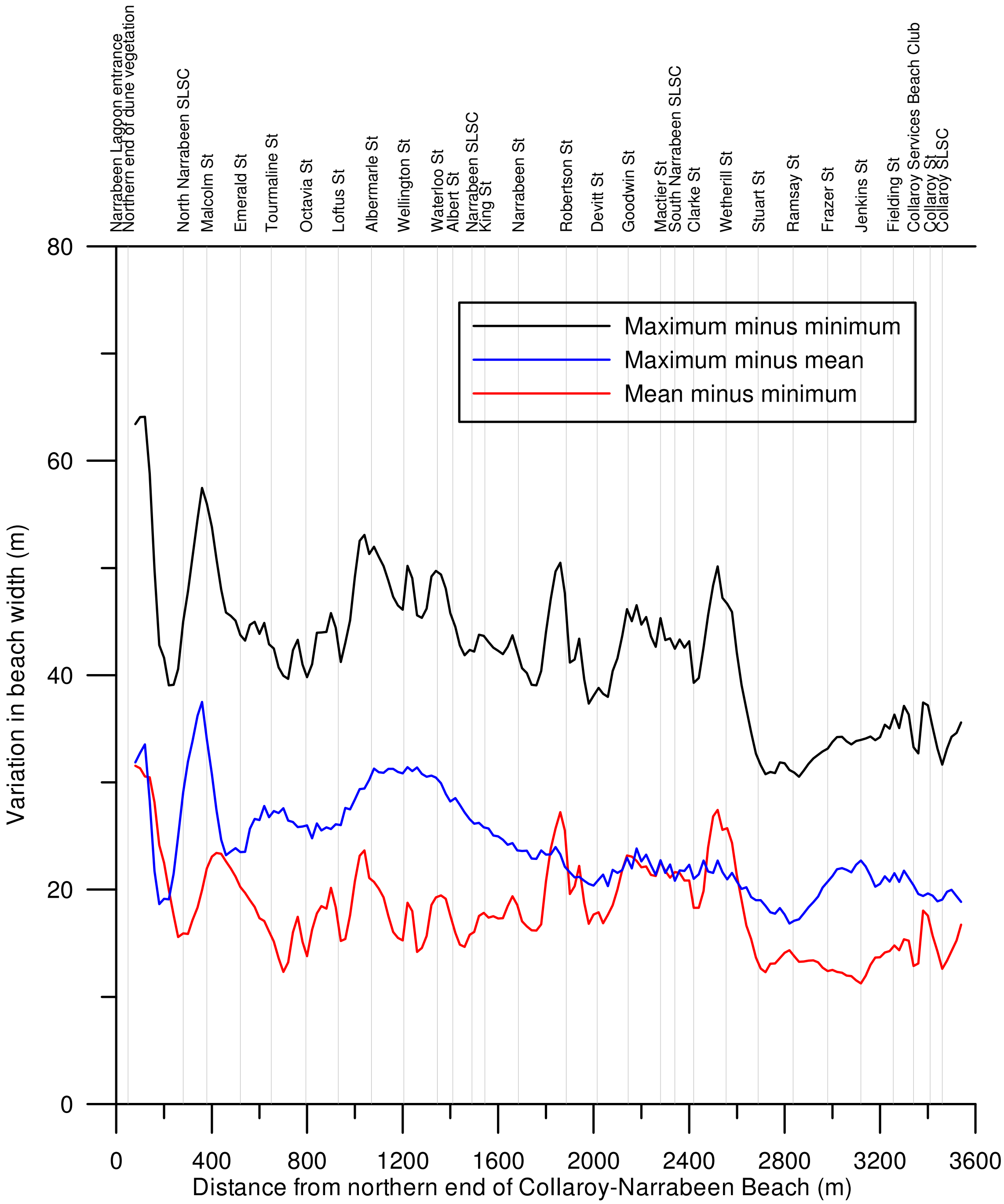

Figure A13: Maximum variation in beach width and variation relative to mean width along Collaroy-Narrabeen Beach

A3. PHOTOGRAPHS

A3.1 Collaroy-Narrabeen Beach

The southern portion of Collaroy-Narrabeen Beach is backed by a seawall and promenade, incorporating Collaroy Surf Life Saving Club (SLSC), see Figure A14. Collaroy Services Beach Club (Figure A15) is located at the northern limit of this promenade, with an outdoor dining area ("The Deck") leased by Collaroy Beach (Surf Rock) Hotel further north (Figure A16). A car park (just visible in Figure A16) extends for about 230m north of the Collaroy Services Beach Club, with private residential development commencing north of Jenkins Street.

North of Jenkins Street, the beach is intensively developed (mainly with residential development) to Devitt Street, a distance of about 1km (see Figure A17 to Figure A24 for example photographs). South Narrabeen SLSC is located within this area, between Clarke Street and Mactier Street (Figure A23). The Jenkins Street to Devitt Street area also includes the high rise unit blocks "Shipmates" and "Flight Deck" (located immediately south of Ramsay Street, see Figure A18), and "Marquesas" (twin towers located just south of Devitt Street, in background of Figure A25).

The 600m north of Devitt Street (north of the twin "Marquesas" towers to Albert Street) is mostly open space parkland (Figure A25), with Narrabeen SLSC located in this area (Figure A26). North of Albert Street, residential development extends for a further 1km (see Figure A27 to Figure A30 for example photographs). The most northern 400m stretch of beach comprises Birdwood Park (Figure A32), within which North Narrabeen SLSC (Figure A31) is located.

Oblique aerial photographs of parts of the study area were taken on 28 July 2007, with the beach in an eroded state, and supplied by Council. These photographs are shown in Figure A33 to Figure A43. Exposure of protective works (mainly rock) was evident in some of these photographs, in particular between Stuart Street and just north of Clarke Street (Figure A36 to Figure A38).

Figure A14: Seawall south of Collaroy SLSC at Collaroy Beach, 30 March 2008

Figure A15: View of Collaroy Services Beach Club, looking north, 27 February 2009

Figure A16: Outdoor dining area and car park north of Collaroy Services Beach Club, 14 November 2010

Figure A17: View from "The Breakers" (north of Jenkins Street) looking north along Collaroy-Narrabeen Beach, 27 February 2009 ("Flight Deck" in background)

Figure A18: View of "Flight Deck" (left) and "Shipmates" (right) structures located south of Ramsay Street, 29 July 2007

Figure A19: View of Collaroy Beach south of Wetherill Street, with rock works extending to Stuart Street staircase in background, 30 March 2008

Figure A20: View of Collaroy-Narrabeen Beach from Stuart Street to Wetherill Street (at staircase location), 30 March 2008

Figure A21: View of development at Narrabeen Beach between Wetherill Street and Clarke Street, 30 March 2008

Figure A22: View of Narrabeen Beach north of Clarke Street, 30 March 2008 (red marquee at South Narrabeen SLSC in background)

Figure A23: View of Narrabeen Beach north of Clarke Street, including South Narrabeen SLSC, 29 July 2007

Figure A24: View of Narrabeen Beach north of Mactier Street, 29 July 2007

Figure A25: View south over "The Gardens" towards the twin "Marquesas" towers, 14 February 2009

Figure A26: View of Narrabeen SLSC from Narrabeen Beach, 14 February 2009

Figure A27: View north along Narrabeen Beach from near Wellington Street, 14 February 2009

Figure A28: View of dune at Narrabeen Beach near Albemarle Street, 14 February 2009

Figure A29: View of dune at Narrabeen Beach near Octavia Street, 14 February 2009

Figure A30: View south along Narrabeen Beach from near Emerald Street, 14 February 2009

Figure A31: North Narrabeen SLSC, 14 February 2009

Figure A32: View (of Birdwood Park) north from near North Narrabeen SLSC, 14 February 2009

Figure A33: Oblique aerial view of southern end of Collaroy Beach (south of Collaroy Street), 28 July 2007

Figure A34: Oblique aerial view of Collaroy Services Beach Club and car park to north, 28 July 2007

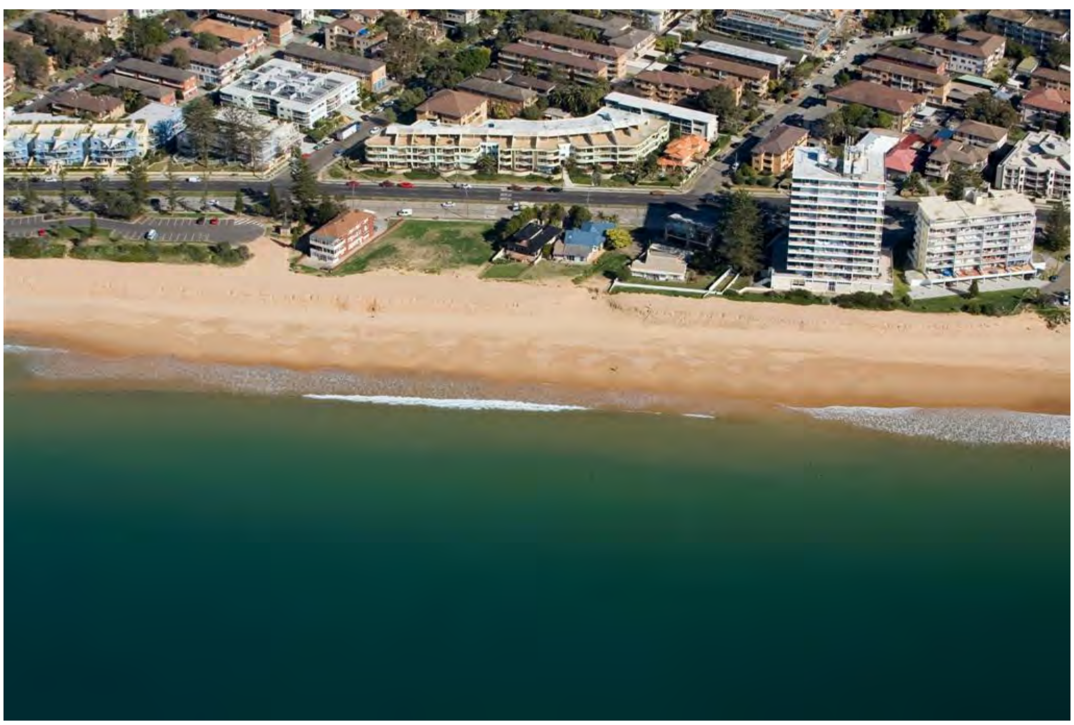

Figure A35: Oblique aerial view of Jenkins Street to Ramsay Street area of Collaroy Beach, 28 July 2007

Figure A36: Oblique aerial view of Ramsay Street to Wetherill Street area of Collaroy Beach, 28 July 2007

Figure A37: Oblique aerial view of Stuart Street to north of Wetherill Street along Collaroy-Narrabeen Beach, 28 July 2007

Figure A38: Oblique aerial view of south of Clarke Street to Mactier Street along Narrabeen Beach, 28 July 2007

Figure A39: Oblique aerial view of south of Mactier Street to Goodwin Street along Narrabeen Beach, 28 July 2007

Figure A40: Oblique aerial view of Goodwin Street to north of Devitt Street along Narrabeen Beach, 28 July 2007

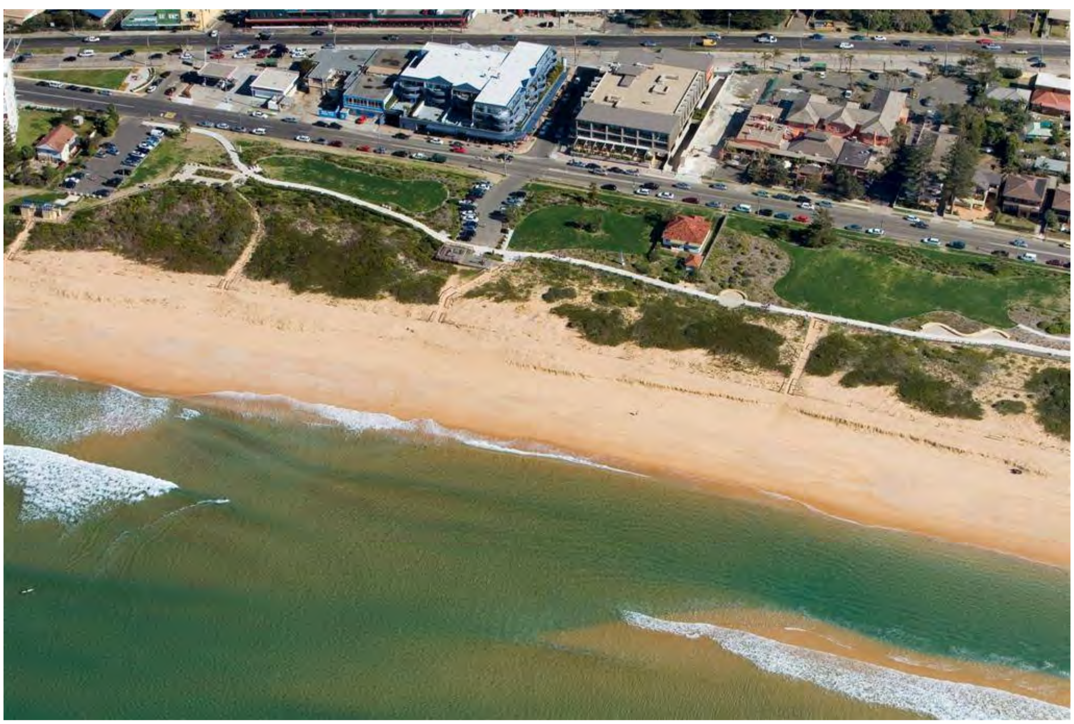

Figure A41: Oblique aerial view of The Gardens Reserve north of Devitt Street along Narrabeen Beach, 28 July 2007

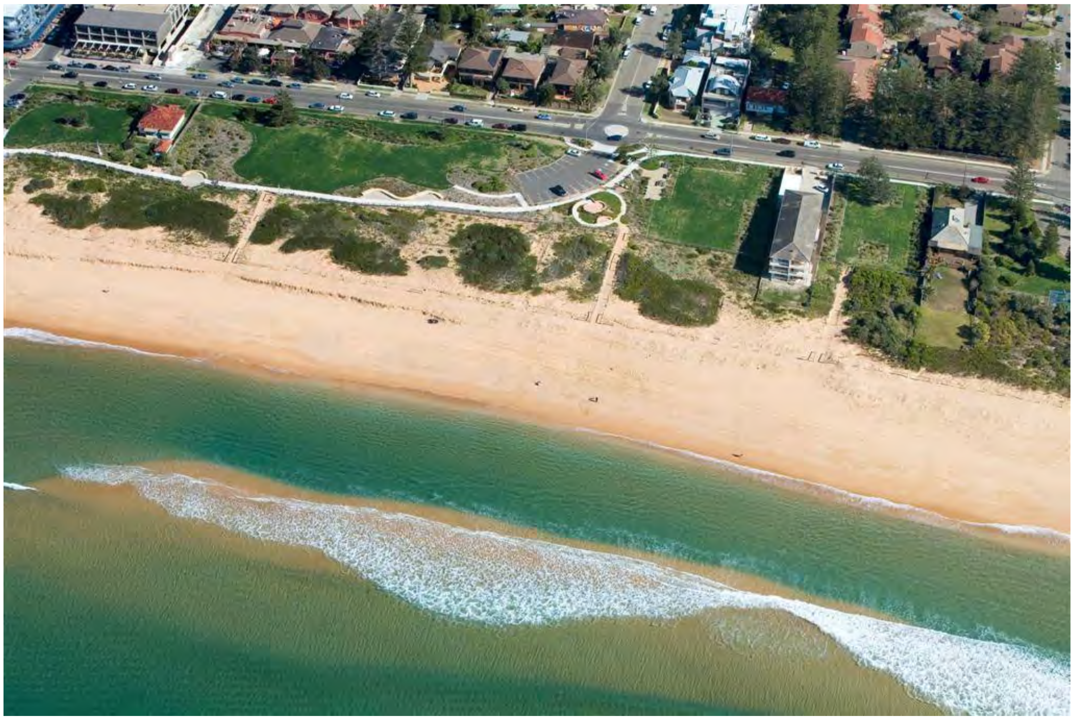

Figure A42: Oblique aerial view of Robertson Street to King Street along Narrabeen Beach, 28 July 2007

Figure A43: Oblique aerial view of northern end of Narrabeen Beach (north of Emerald Street), 28 July 2007

A3.2 Fishermans Beach

Residential development is located landward of the northern half of Fishermans Beach (see Figure A44 to Figure A46 for example photographs). Long Reef Golf Club is located landward of the southern half of the beach, with an access road to Long Reef headland and car parking areas situated immediately landward of the beach in this area. A boat ramp is located to the south-east of the Long Reef Golf Club clubhouse (Figure A47 and Figure A48). A Warringah Surf Rescue building[9] and Long Reef Fishing Club Hut[10] are located at the eastern end of the beach (Figure A49).

Figure A44: View over northern end of Fishermans Beach, 2 November 2008 (car park north of Florence Avenue visible)

[9] This building, also known as the Warringah Surf Rescue Radio Base (or Communications Base), includes an amenities block (toilets) accessible to the general public. The building is used by Council's Beach Services Unit and Surf Life Saving Sydney Northern Beaches Incorporated (Warringah Council, 2004). The ground floor is also used by Long Reef Fishcare and Reefcare volunteers and as a general Council meeting room. As of January 2014, future uses of this building are under consideration, with Surf Lifesaving Sydney Northern Beaches in the process of negotiating a lease for the site with the NSW Government. A public meeting is to be held on 10 February 2014 to seek the views of the local community regarding the future of the building.

[10] This structure is understood to have been occupied by Long Reef Fishing Club for over 40 years, and has been denoted as the "Long Reef Fishing Club Hut" herein, based on advice from Mr Steve Bax (formerly of Council).

Figure A45: View along Fishermans Beach to south of Florence Avenue, 2 November 2008

Figure A46: View along Fishermans Beach to south-east from Ocean Grove, 28 February 2009

Figure A47: Boat ramp at Fishermans Beach, 28 February 2009

Figure A48: View of Fishermans Beach east of boat ramp, 30 March 2008

Figure A49: Long Reef Fishing Club Hut (centre) and Warringah Surf Rescue building (right) at eastern end of Fishermans Beach, 28 February 2009

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Appendix B:
Development of Surf Life Saving Club Structures

CONTENTS

B1 DEVELOPMENT OF SURF LIFE SAVING CLUB STRUCTURES

B1.1 Introduction

In this Appendix, the historical development of the four Surf Life Saving Club (SLSC) structures in the study area is described, moving north to south.

B1.2 North Narrabeen SLSC

Based on discussions in 2011 with the North Narrabeen SLSC President, Mr Michael McDermott, it was determined that the present SLSC building was constructed in 1975, with conventional raft slab foundations on sand. Subsequent extensions on the landward side of this building were completed in 1983 by SLSC members. Mr McDermott advised that no protective works had been constructed seaward of the SLSC building, and that the building had never been threatened by erosion or inundation during storms. The building is located about 35m to 38m landward of the seaward edge of dune vegetation as evident in 2009 and 2011 aerial photography.

The previous SLSC building was constructed in 1932 and was located adjacent to Malcolm Street. Over its life between 1932 and 1975, coastal erosion up to its footings did occur but the overall structural stability of the building was not considered to be under threat (Mr Michael McDermott, personal communication). Review of 1943 photography indicated that 6 houses were also located to the north of the SLSC at that time. The position of the SLSC in 1943 is superimposed on a 2009 aerial photograph in Figure B1. Its seaward face was about 25m to 28m landward of the sand/vegetation interface as evident in 2009 and 2011 aerial photography. A 1963 photograph (Figure B2) indicates the general lack of dune vegetation at that time.

Figure B1: Location of North Narrabeen SLSC from 1932 to 1975

Figure B2: North Narrabeen SLSC in 1963 (from Ogden, 2011)

B1.3 Narrabeen SLSC

Narrabeen SLSC officially commenced in July 1964, although there is evidence that some form of rescue service had operated from the same approximate area since the early 1900's. The original clubhouse was an old timber cottage, but has been substantially altered, renovated and extended since then[1].

The current SLSC building is located around 45m landward of the sand/vegetation interface as evident in 2009 and 2011 aerial photography. It is expected to have been constructed on conventional foundations.

B1.4 South Narrabeen SLSC

Patrols commenced at South Narrabeen SLSC in 1922, with the SLSC officially opened in December 1923[2]. It is expected that the SLSC building was constructed on conventional foundations.

Protective works are located seaward of South Narrabeen SLSC, with rock dumped at this and surrounding locations during storms in 1974 (MHL, 1999), see Figure B3.

[1] Information derived from http://www.narrabeach.org.au/, accessed March 2011.
[2] Information derived from http://www.southnarrabeensurfclub.org/pages/club-history.php, accessed March 2011.

Figure B3: Protective works near South Narrabeen SLSC sometime between 1969 and 1974 (courtesy of Mr Don Champion)

B1.5 Collaroy SLSC

Brawley (1995) noted that following construction of the first Collaroy SLSC building in 1911, it was destroyed by storms during the 1913 to 1914 season. The SLSC structure was rebuilt and relocated several times before the brick building existing today was constructed. In the 1950's a number of alterations were made to the previous brick building including the addition of a second floor (refer Figure B4), cement rendering and construction of a sandstone block seawall along the seaward face of the building. Brawley (1995) also noted that the seawall was reinforced by Council after an easterly gale caused inundation of the lower floor of the new building.

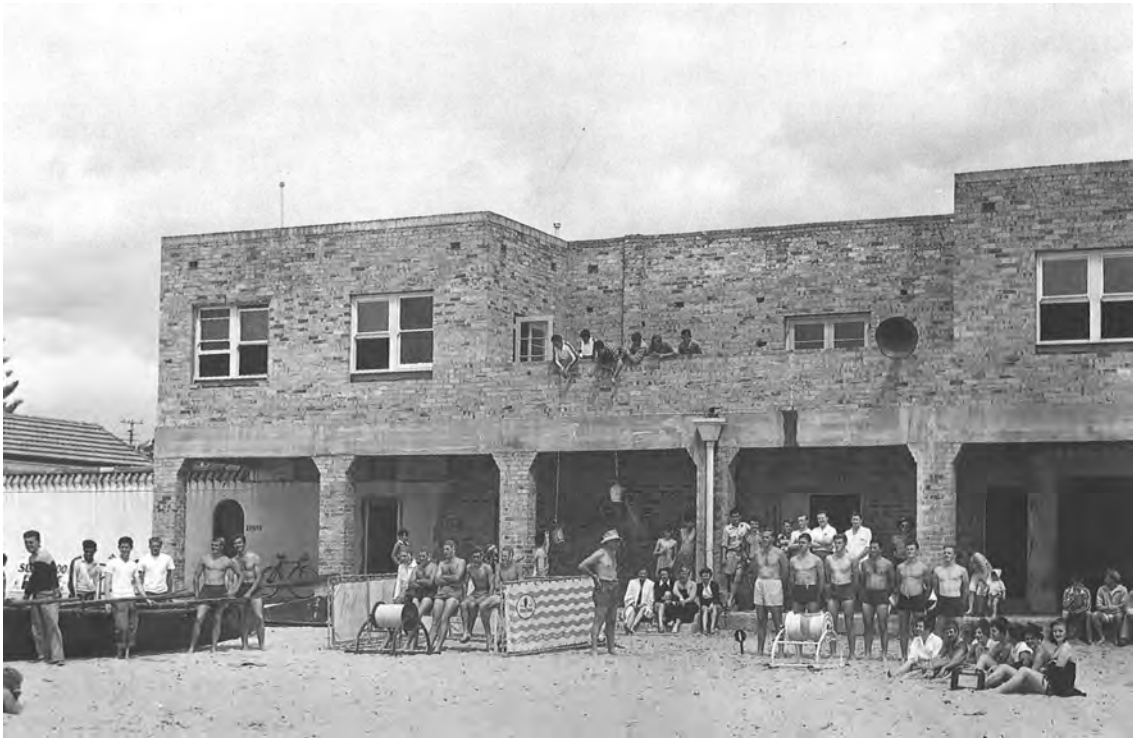

Figure B4: Collaroy SLSC building in the 1950's (Brawley, 1995)

Storms in 1967 caused the seawall seaward of the SLSC to collapse, and a new stepped concrete seawall with a deeper toe level was constructed (see Figure B5 and Figure B6). This concrete seawall is understood to be supported by a substantial sheet pile wall extending about 10m below the promenade level to approximately -6m AHD (Patterson Britton & Partners, 1993). While it is not known whether the sheet piling returns around the ends of the SLSC building, or whether protection against outflanking is afforded by the adjacent sandstone seawall, there is apparently some degree of protection in place to combat any possible undermining of the building.

Figure B5: Construction of new seawall at Collaroy SLSC in the late 1960's, following storm damage (Brawley, 1995)

Figure B6: View of Collaroy SLSC clubhouse and stepped seawall in 1975 (Brawley, 1995)

Appendix C: Information on Most Significant Storms of 1945, 1967 and 1974

CONTENTS

C1 INFORMATION ON KEY STORMS

C1.1 Introduction

In this Appendix, information is provided on the key coastal storms that occurred in 1945, 1967 and 1974.

C1.2 1945 Storms

Based on review of 1943 aerial photography and reference to PWD (1987), it was evident that there was extensive development (at least 9 properties developed) between the present Collaroy Services Beach Club and Jenkins Street in 1943, in the area that now forms the northern portion of the Collaroy Beach car park. The seaward face of this development was generally in the order of 5m to 10m seaward of the present seaward edge of the car park.

PWD (1987) noted that development at most of these properties was damaged in the June 1945 storm, with the development in this area subsequently being removed (and properties resumed) in February 1946[1]. A view of some of the damage that occurred (from the *Sydney Morning Auditor*, 14 June 1945, supplied courtesy of James Carley of WRL) is shown in Figure C1.

Figure C1: Damage to houses between Fielding Street and Jenkins Street, June 1945

Arlington Hall (now Collaroy Services Beach Club) was also damaged in the 1945 storms, and was declared unsafe for many years after (PWD, 1987). This was despite the dumping of "huge concrete

[1] The lot immediately north of Jenkins Street was also resumed at that time.

tank traps" as emergency protection. A house north of Goodwin Street was also undermined in the 1945 storms, and moved to an adjacent vacant block.

C1.3 1967 Storms

As described by PWD (1987), in the 1967 storms a 5m depth of sand was eroded at the "Flight Deck", unit block, exposing the piled foundations (Figure C2). As a result, the foundations of this structure and the adjacent "Shipmates" unit block were protected by emergency dumping of hundreds of tonnes of fill and construction of a rubble wall, as visible in Figure C3 and Figure C4.

Figure C2: Exposure of "Flight Deck" foundations as a result of 1967 storms (from PWD, 1985)

Figure C3: Rock protection visible at "Flight Deck" (left) and "Shipmates" (right) sometime between 1969 and 1974 (courtesy of Mr Don Champion)

Figure C4: Closer view of rock protection visible at "Flight Deck" sometime between 1969 and 1974 (courtesy of Mr Don Champion)

A seawall north of Stuart Street also partially collapsed as a result of the 1967 storms (PWD, 1987). PWD (1985) noted storm cuts protruding 10m to 15m into some properties as a result of the 1967 storms. They also noted that after these storms, Council resolved to prevent further beachfront unit development in the LGA.

C1.4 1974 Storms

Foster et al (1975) noted that the major storms of May-June 1974:

- destroyed dunes at the Narrabeen Lagoon entrance;
- washed half of the road north of the Ocean Street bridge away (peak water level at this location was about 2.4m AHD)[2];
- damaged the road to the North Narrabeen rock baths;
- caused minor damage to the adjacent structure;
- led to severe erosion of beach and dunes over the central-northern section of Collaroy-Narrabeen Beach threatening many homes; and
- resulted in emergency rock protection being used to prevent damage to the "Marquesas" units.

Foster et al (1975) also noted that damage at Collaroy Beach was minor and erosion was not as severe as in 1967, although a stormwater pipe opposite Collaroy Street was destroyed and there was minor damage to the seawall and pavement in this area.

[2] PWD (1987) noted that 0.3m diameter rocks were washed up to 40m into the Caravan Park adjacent to Narrabeen Lagoon during this event.

PWD (1987) noted that 300 workers were involved in the effort to save houses at Collaroy-Narrabeen Beach in the 1974 storms. Photographs of rock exposed rock at the beach in the late 1970's are provided in Figure C5 and Figure C6[3].

Figure C5: Erosion and exposed rock between Wetherill Street and Goodwin Street, in around 1977

[3] Photographs supplied by Mr Mark Moratti of OEH.

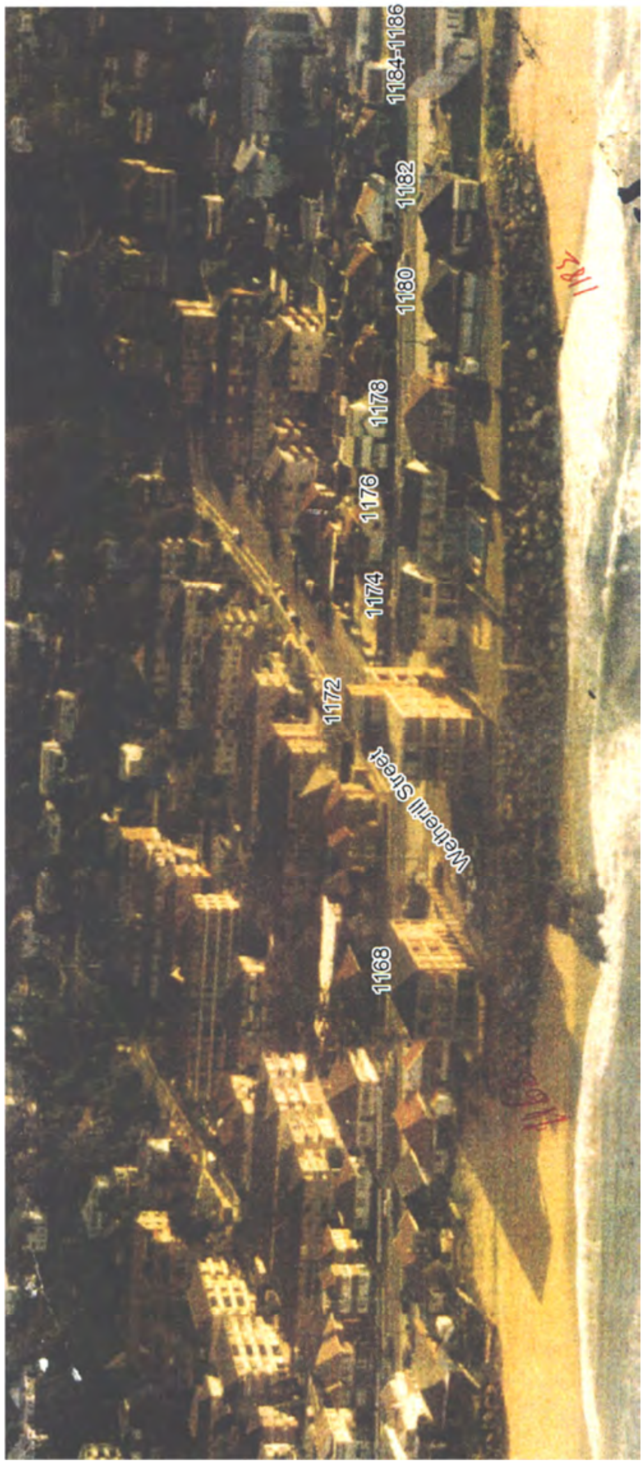

Figure C6: Erosion and exposed rock between Wetherill Street and just south of Clarke Street, in late 1970's (Pittwater Road house numbers shown)

Appendix D:
History of Coastal Management at Collaroy-Narrabeen Beach and Fishermans Beach

CONTENTS

D1. HISTORY OF COASTAL MANAGEMENT IN STUDY AREA

D1.1 1974 to 1985 Period: The Beginnings of Strategic Coastline Management and Dune Management

D1.1.1 General Outline

Major coastal storms in 1974, which resulted in loss of public and private assets and adversely affected beach amenity (through construction of piecemeal protective works) in NSW, led to attention being focussed on better planning and management of the coastal zone (PWD, 1985).

In 1976, the NSW Government introduced a Beach Improvement Programme which provided funds for Councils to restore and enhance public beach amenity. This funding, plus Commonwealth unemployment relief grants and Council funds, were used to undertake works at all beaches in Warringah including the study area (PWD, 1985).

As documented in Warringah Shire Council (1978), a seminar was held at Council on "control of coastal erosion" in October 1978. Attendees included Councillors, Council staff, three local State members of parliament, staff from NSW government departments (Department of Public Works, Planning and Environment Commission, Maritime Services Board, Soil Conservation Service, Department of Mines, State Pollution Control Commission, and National Parks and Wildlife Service), academics, consulting engineers, staff from other Councils, staff from the Australian Museum, and three community groups.

At this 1978 seminar, it was recognised that long term planning measures were essential if coastal erosion was to be effectively controlled. Actions that Council should take were considered to include education of Warringah citizens on coastal management problems, maintenance of dune stabilisation measures, and formulation of a management scheme for beaches.

The *Coastal Protection Act* was passed by the NSW Government in 1979, partly to encourage Council's in ensuring that future development was not adversely affected by coastal processes, although PWD (1985) recognised that most privately owned areas in Warringah LGA had already been developed at that time.

In 1981, a working party was established comprising Warringah Council and PWD staff, with the aim of integrating Council's management and planning with coastal engineering advice to produce an overall strategy for coordination of beach reserves management and identification of areas of the coastal zone that required specific development controls (PWD, 1985).

This resulted in the completion of an investigation by PWD (1985) in which coastline management strategies were developed for the beaches and headland areas of the entire Warringah Shire Council LGA (which at that time, extended from Freshwater to Palm Beach, thus including the current Pittwater LGA). PWD (1985) prepared these strategies (see Section D1.2) to provide a framework within which detailed Council planning could be undertaken.

D1.1.2 Dune Management

At the northern end of Collaroy-Narrabeen Beach, the dune at Birdwood Park was raised substantially (anthropogenically) after the 1974 storms.

The Birdwood Park dune was constructed and stabilised to a height of between 6m and 7m AHD in March-June 1975, after having been completely destroyed in the May-June 1974 storms (Patterson Britton & Partners, 2002). Examination of photogrammetric data indicated that dune heights at Birdwood Park after the 1974 storms were between about 2.5m and 3.5m AHD, and were generally between 6m and 8m AHD by 1985[1]. An example profile plot[2] indicating the variation in dune elevation over time is provided in Figure D1.

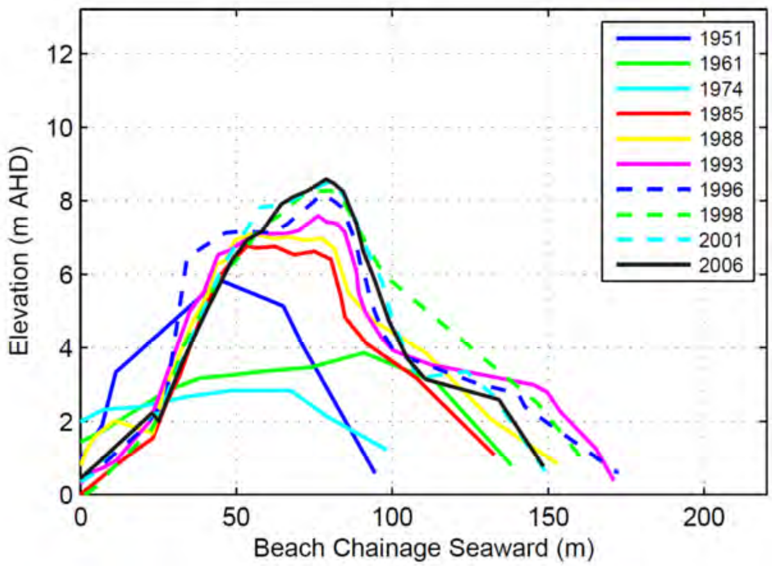

Figure D1: Variation in dune elevation at Birdwood Park from 1951 to 2006 at shore-normal profile about 130m north of North Narrabeen SLSC

From 1980 to 1981, dune reformation and stabilisation was undertaken at Collaroy (PWD, 1985). Also, the formation of a more substantial and stabilised dune occurred at the northern end of Narrabeen Beach in 1984, by pushing sand landward from the beach berm (PWD, 1987). Landscaping and car park improvements were also undertaken at that time (PWD, 1985).

D1.2 Strategies Recommended in PWD (1985)

D1.2.1 Collaroy-Narrabeen Beach

Some of the strategies recommended in PWD (1985) for Collaroy-Narrabeen Beach were:

- dune stabilisation works;
- adopting suitable development controls;
- consideration of relocating Collaroy SLSC landward when redeveloped;
- purchasing privately owned properties when offered for sale; and,
- development of a revetment (seawall) policy.

[1] Note that prior to the 1974 storms, dune heights in the Birdwood Park area were generally between about 3m and 4.5m AHD (and up to 6m AHD in 1951). That is, the 1975 dune works created a significantly larger dune than had existed previously.
[2] At about 130m north of North Narrabeen SLSC.

D1.2.2 Fishermans Beach:

Some of the strategies recommended in PWD (1985) for Fishermans Beach were:

- consideration of construction of a buried revetment between Fox Park and the boat ramp;
- adopting suitable development controls;
- reducing the number of stormwater outlets;
- controlling unchannelled stormwater flow at the seaward ends of Florence Avenue, Ocean Grove and Anzac Avenue; and,
- consideration of the risk of oceanic inundation to houses in the low area north of Fox Park.

D1.3 1986 to 1991 Period: Initial Hazard Definition and Emergency Action Plan

In the 1986 to 1991 period, a number of reports were completed related to Collaroy-Narrabeen and Fishermans Beach.

A coastal processes and coastline hazard quantification study for these beaches was completed by PWD (1987). No coastline hazard lines were defined in this investigation.

A review of existing planning and building constraints at these beaches, in the light of the hazard quantification of PWD (1987), was completed by Nielsen Lord Associates (1988). Nielsen Lord Associates (1988) also more precisely quantified some of the hazards identified by PWD (1987).

Nielsen Lord Associates (1989) completed an investigation of appropriate coastline management options in the study area in the light of the defined hazards. Following a period of public consultation, the preferred management option was determined to be beach nourishment in combination with stormwater outlet improvements, which was formally adopted by Council on 17 July 1990 (Patterson Britton & Partners, 1993).

Coastline hazard mapping of Collaroy-Narrabeen Beach and Fishermans Beach was completed by Nielsen Lord Associates (1990), in which hazard lines were delineated for immediate and 50 year planning periods, utilising the values quantified in Nielsen Lord Associates (1988).

Nielsen Lord Associates (1990) considered that it was most unlikely that a 50 Year Hazard Line would eventuate, because the community or land owners would most likely take action to protect properties during severe storms. That is, they expected that the past practice of dumping fill and rock would continue.

Geomarine (1991) completed an investigation in which coastline hazard zones (or lines) were delineated for Collaroy-Narrabeen Beach and Fishermans Beach, expanding on Nielsen Lord Associates (1990) by providing details on foundation design requirements for residential beachfront development at these beaches. Geomarine (1991) noted that criteria for new development at these beaches had been defined on the basis of the hazard lines (that is, by applying adequate setbacks) and special foundation conditions. However, they also noted that these criteria were only interim measures to ensure safety of new developments until a long term management plan had been implemented at these beaches.

Accordingly, Geomarine (1991) did not determine any coastline hazard lines for future conditions. That is, hazard lines were only determined for the immediate planning period, and no account was made of any future long term recession due to sea level rise nor net sediment loss.

The hazard lines determined by Geomarine (1991) were the immediate landward edges of the Zone of Wave Impact, Zone of Slope Adjustment and Zone of Reduced Foundation Capacity as per Nielsen et al (1992).

"Revised Interim Building and Development Guidelines for Collaroy/Narrabeen/Fishermans Beach", which were based on Geomarine (1991), were adopted by Council on 20 August 1991. This essentially stipulated that major development should be located landward of the Geomarine (1991) Zone of Wave Impact (denoted as the 1991 ZWI herein).

A *Warringah Shire Council Emergency Storm Plan* was developed in 1991. As described by Patterson Britton & Partners (2000), the *Warringah Shire Council Emergency Storm Plan* was divided into seven sections (each dealing with a certain procedure), namely monitor and predict, pre-standby arrangements, standby procedures, mobilisation and coordination of staff/resources, notification of affected residents, surveillance and restoration, and clean-up. It was developed with the aim of achieving protection of lives, protection of public buildings, protection of public lands, to assist in the protection of private property, and to minimise the impacts of severe intensity storms within the above priorities.

D1.4 1992 to 1997 Period: Management Options for Collaroy-Narrabeen Beach

As an outcome of the Nielsen Lord Associates (1989) study, Patterson Britton & Partners (1993) completed an investigation into the feasibility and cost of beach nourishment and stormwater improvements at Collaroy-Narrabeen Beach, including consideration of suitable sand sources. Patterson Britton & Partners (1993) concluded that the most suitable coastline management option at Collaroy-Narrabeen Beach was likely to be upgrading of seawalls combined with beach nourishment, which was found to be substantially (about $13 million) cheaper than undertaking "massive" beach nourishment in isolation.

The *Collaroy Narrabeen Coastline Management Plan* was completed by Warringah Council (1997). Coastline management strategies and actions that were adopted included:

1. surveying and assessing existing seawalls;
2. selective reconstruction of existing seawalls and infilling of gaps;
3. undertaking moderate beach nourishment in association with the above;
4. selective voluntary purchase of single residential properties;
5. revision of the coastal emergency management procedure for Collaroy-Narrabeen Beach;
6. reviewing building lines for the beachfront; and,
7. maintaining/reviewing building and development controls for the beachfront.

Related to Items 6 and 7 above, as part of the *Collaroy Narrabeen Coastline Management Plan*, the Geomarine (1991) hazard lines were adopted by Council and became part of "Collaroy/Narrabeen Coastline Management Plan – Development Guidelines for Collaroy/Narrabeen Beach"[3] as per Appendix B of the Plan. This stipulated that all new major development had to be located landward of

[3] Fishermans Beach was included in mapping, so was also covered in this document despite not being included in the title.

the Zone of Wave Impact defined by Geomarine (1991), reiterating use of the 1991 ZWI as adopted in 1991, amongst other controls. Ultimately, this information was incorporated into Schedule 13 of the *Warringah Local Environmental Plan 2000* and continued to be an important tool in Council's assessment of Development Applications along Collaroy-Narrabeen Beach.

D1.5 1998 to 2005 Period: Seawall and Further Emergency Considerations

Studies relating to surveying and assessing existing seawalls and design of seawall upgrades[4] were completed by MHL (1999), Patterson Britton & Partners (1999), Jeffery and Katauskas (2000), and Patterson Britton & Partners (2001). A Statement of Environmental Effects for the seawall upgrade was prepared by Halliburton KBR Pty Ltd (2002).

Patterson Britton & Partners (2000) completed a *Draft Coastal Erosion Emergency Sub Plan for Collaroy-Narrabeen Beach*[5]. A working group was subsequently established with representatives from the State Emergency Service, the then Department of Infrastructure Planning and Natural Resources (now Office of Environment and Heritage [OEH]), Warringah Council and Patterson Britton & Partners. Using the *Draft Coastal Erosion Emergency Sub Plan* as a basis, and following further definition of the role and responsibilities of the State Emergency Service (SES), the working group produced a proposed Annex to the Manly-Warringah-Pittwater Local Flood Plan. This Annex was denoted as "Annex A: The Management of Coastal Erosion, Collaroy-Narrabeen Beach", and dated October 2001.

The Annex was not formally incorporated into the Manly-Warringah-Pittwater Local Flood Plan due to a number of factors:

- the necessity for approvals under the *Environmental Planning and Assessment Act 1979* prior to implementation of protective measures such as placement of rock, which would not be overridden by provisions in the *State Emergency and Rescue Management Act 1989*;
- uncertainty as what should be protected (e.g. protection of fences, gardens and backyards versus buildings at imminent threat);
- uncertainty as to funding sources for any emergency works at that time; and,
- the recommendation of the Warringah Coastal Management Committee at the time that no emergency rock placement should take place on the public beach to protect private property landward of the beach.

Having regard to the above issues, Council staff developed a document entitled "Coastal Storm Erosion Response Protocol Collaroy / Narrabeen Beach", which was included in a report to a Council meeting on 26 July 2005. In the Protocol, details of the response and actions required of relevant parties at times of erosion events of varying magnitude (including those required of Council and the SES), were detailed.

To further assist in the emergency management process, Patterson Britton & Partners (2005) completed an information dossier on development from the Collaroy Services Beach Club to Devitt Street at Collaroy-Narrabeen Beach. In this dossier, information pertinent to the risk to dwellings

[4] Related to Items 1 and 2 of the actions resulting from the *Collaroy Narrabeen Coastline Management Plan* listed in Section D1.4.
[5] Related to Item 5 of the actions resulting from the *Collaroy Narrabeen Coastline Management Plan* listed in Section D1.4

during coastal erosion events was listed (such as the extent of protective works), and it was designed to be able to be used in the field during emergency management situations[6].

D1.6 2004 to 2009 Period: Imaging, Surveying and Updated Hazard Definition

The Water Research Laboratory (WRL) of the University of New South Wales (UNSW) installed an ARGUS coastal imaging system at Collaroy-Narrabeen Beach in July 2004, with funding assistance from Council. Three annual monitoring reports have been completed since the installation of the system, as documented in Turner (2005, 2006) and Blacka et al (2007), for the years ending June 2005, June 2006 and June 2007 respectively.

The coastal imaging system comprises five cameras with automated collection, analysis and storage of pictures. These pictures are then processed to observe and quantify coastline variability and change. Quantitative information is derived by conversion of two dimensional image coordinates to three dimensional ground coordinates.

Three types of images are collected every daylight hour, namely a snap-shot, time exposure (averaging 1 picture per second for 10 minutes) and variance (displaying the variance of light intensity over the same 10 minute period) image . Time exposure images are particularly useful for identifying the shoreline, and nearshore bars. Variance images can also assist in identifying the shoreline. A fourth image is generated each day, namely a daily average time exposure image. These images are uploaded to the world wide web.

The main image analysis output is information on shoreline position, from which beach width variation with time can be derived along Collaroy-Narrabeen Beach between Jenkins Street in Collaroy and Devitt Street in Narrabeen.

Mitchell Harley, a then Doctor of Philosophy (PhD) candidate at WRL, commenced approximately monthly Real Time Kinematic Global Positioning System (RTK-GPS) sub-aerial surveys of Collaroy-Narrabeen Beach in May 2005 (Harley et al, 2006, 2007). Each survey includes about 10,000 coordinated level readings obtained by quad bike traverses of the beach at Spring low tide. These surveys are ongoing. Related to this work, Harley's PhD thesis (Harley, 2009) was completed in 2009.

Council recently jointly funded continuation of the imaging system and monthly surveys as part of being a Project Partner in an Australian Research Council Linkage Project administered by the University of New South Wales. The title of the project was "Australian Coastal Observation Network: monitoring and forecasting coastal erosion in a changing climate". Council funding for this monitoring ended in June 2013.

Related to Items 6 and 7 of the actions resulting from the *Collaroy Narrabeen Coastline Management Plan* listed in Section D1.4, WorleyParsons (2009) completed a review of the Geomarine (1991) coastline hazard lines for Collaroy-Narrabeen Beach and Fishermans Beach. As a result, updated hazard lines were developed for Immediate (2009), 2059 and 2109 planning periods. In WorleyParsons (2009), discussion was also included on the implications of the defined hazards on potential development controls.

[6] Indeed, the dossier was used by Council staff to assist in providing advice to residents affected by coastal storms at Collaroy-Narrabeen Beach in June-July 2007.

WorleyParsons (2009) recommended that in the interim before the hazard lines they developed were adopted as development controls (or used to inform the controls), preparation of an Emergency Action Plan (EAP) should be prioritised for the Collaroy-Narrabeen Beach and Fishermans Beach area. This was because it was considered that an EAP was likely to be the main mechanism available for management of coastline hazards in this area in the near future at that time.

D1.7 2010 to 2014 Period: Emergency Action Subplan and North Narrabeen Dune Issues

D1.7.1 Emergency Action Subplan

A *Coastal Erosion Emergency Action Subplan for Beaches in Warringah* (including the study area) was prepared by WorleyParsons (2012a, b). This was certified by the NSW Minister for the Environment on 1 May 2012 as (part of) a CZMP under the *Coastal Protection Act 1979*, as notified in the *Government Gazette of the State of New South Wales*, Week No. 36/2012 (7 September 2012, containing numbers 88, 89 and 90, page 3930).

In WorleyParsons (2012a, b), details were included on:

- approvals required for implementation of emergency protective works both for landowners and Council;
- roles and responsibilities of various authorities in coastal emergency management;
- evaluation of potential emergency protection measures; and
- proposed Council actions before, during and after coastal storms (including discussion on criteria or thresholds to initiate actions).

A relative assessment of immediate risk to private and public property in Warringah from damage due to coastal erosion was also included in WorleyParsons (2012a, b).

In WorleyParsons (2012a, b), it was emphasised that landowners considering protecting property in a coastal emergency must act well in advance of the emergency occurring, including having development consent for rock protective works (for example) prior to placement of such works. Use of sand-filled geotextile containers (sand bags) was not recommended due to lack of stability and difficulty in placement at times of storms.

In WorleyParsons (2012a, b), it was stated that Council did not consider that it had a responsibility to protect private property from coastal erosion and inundation hazards, and did not intend to do so. This remains the current position of Council.

In WorleyParsons (2012a, b) it was noted that Council was not authorised to and would therefore not install works to protect public assets in the study area, as environmental assessments of any potential works had not been undertaken. However, it was stated that it was Council's intention to investigate the feasibility and appropriateness of undertaking such works in the future. This has been included as an action in the CZMP herein, as well as other relevant actions from WorleyParsons (2012a, b).

D1.7.2 North Narrabeen Dune Issues

As discussed in Section D1.1.2, the Birdwood Park dune north of North Narrabeen SLSC has been growing in volume and elevation since 1975. There has been community pressure for lowering of the dunes seaward and north of North Narrabeen SLSC for some time, with community members seeking to improve views of the beach and ocean. Some also claimed that the dune was capturing sand leading to degraded surf quality.

In relation to this and other matters, a draft "North Narrabeen Beach Reserve and Birdwood Park Masterplan" was completed in May 2012, and placed on public exhibition. As part of reporting for this, Water Research Laboratory [WRL] (2012) undertook a feasibility study into modification of the North Narrabeen and Birdwood Park sand dunes to alleviate line of sight issues from the SLSC area to the beach. This feasibility study was focused on investigating the likelihood of increased risk of coastal erosion due to dune modifications. WRL (2012) found that sight lines near North Narrabeen SLSC were potentially dominated by high vegetation more so than sand dune elevations, and found that lowering of the Birdwood Park dune to 7m AHD could be acceptable from a coastal engineering perspective. Based on WRL (2012), if the dune was to be reshaped to improve views of the beach while maintaining its protective function, a volume of only 9,500m^3 of sand should be removed from the dune.

On 11 December 2012 Council resolved to adopt a revised Masterplan, with staff to prepare a further report to Council identifying cost estimates and staging of the proposed works. As part of this adopted Masterplan, there is allowance for lowering and managing the dunes seaward of the SLSC, but large scale works on the Birdwood Park dune (north of the SLSC) were not recommended.

The adopted "North Narrabeen Beach Reserve and Birdwood Park Masterplan" is considered to be generally consistent with the CZMP, and any further studies or works in this area should be completed through the Masterplan process ensuring impacts on coastline hazards are taken into account, which is an action included in Section 11 of the main report.

WARRINGAH COUNCIL

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Appendix E: Listing of Addresses at Collaroy-Narrabeen Beach and Fishermans Beach

CONTENTS

E1. INTRODUCTION

In this Appendix, properties within the study area are listed for Collaroy-Narrabeen Beach (Section E2) and Fishermans Beach (Section E3). Properties were included if the 2100 landward edge of the Zone of Slope Adjustment intersected the lot.

Beachfront lots were defined as lots with seaward boundaries directly adjacent to the public “Crown Land under Council management” beach area[1]. Other land within the study area was defined as “non-beachfront”.

[1] Therefore, lots with seaward boundaries directly adjacent to public Council (not Crown) land (with this Council land directly adjacent to the “Crown Land under Council management” beach) were not defined as beachfront (although there is no private land between these lots and the beach, they are setback from the beach and hence should not be classified as beachfront.

E2. COLLAROY-NARRABEEN BEACH

E2.1 Beachfront Properties

Moving south to north, the 377 beachfront addresses in the study area at Collaroy-Narrabeen Beach were as follows (private section plan development unless stated as strata):

- between Collaroy Street and Fielding Street (1 lot, 1 lot address, 1 individual address):
  - Collaroy Services Beach Club (1056-1058 Pittwater Road Collaroy)[2];
- between Jenkins Street and Frazer Street (3 lots, 3 lot addresses, 6 individual addresses):
  - "The Breakers" (1096 Pittwater Road Collaroy, strata) with 4 units (1-4);
  - 1104 and 1106 Pittwater Road Collaroy;
- between Frazer Street and Ramsay Street (4 lots, 4 lot addresses, 65 individual addresses):
  - 1 Frazer Street Collaroy;
  - 1112 Pittwater Road Collaroy (with only direct access to the beachfront, not frontage);
  - "Flight Deck" (1114 Pittwater Road Collaroy, strata) with 36 units (1-36)
  - "Shipmates" (1122 Pittwater Road Collaroy, strata) with 27 units (1-27) plus 3 extra lots for storage
- between Ramsay Street and Stuart Street (10 lots, 10 lot addresses, 10 individual addresses):
  - 1126, 1128, 1130, 1132, 1134, 1136, 1138, 1140, 1142, and 1144 Pittwater Road Collaroy;
- between Stuart Street and Wetherill Street (11 lots, 10 lot addresses, 23 individual addresses):
  - "Stanbury" (1150 Pittwater Road Collaroy, strata) with 14 units (1-14);
  - 1154 Pittwater Road Collaroy;
  - 1156 Pittwater Road Collaroy (2 lots);
  - 1158, 1160, 1162, 1164, 1166a, 1166b, 1168 Pittwater Road Collaroy;
- between Wetherill Street and Clarke Street (7 lots, 7 lot addresses, 13 individual addresses):
  - 1172 Pittwater Road Narrabeen, strata with 6 units (1-6);
  - 1174, 1176, 1178, and 1180 Pittwater Road Narrabeen;
  - 1182 Pittwater Road Narrabeen, strata with 2 units (1-2);
  - 1186 Pittwater Road Narrabeen;
- between Clarke Street and Mactier Street (5 lots, 5 lot addresses, 25 individual addresses):
  - 1190 Pittwater Road Narrabeen;
  - 1192 Pittwater Road Narrabeen, strata with 4 units (1-4);
  - 1194 and 1196 Pittwater Road Narrabeen;
  - 1204 Pittwater Road Narrabeen, strata with 18 units (1-18);
- between Mactier Street and Goodwin Street (9 lots, 8 lot addresses, 14 individual addresses):
  - 1a Mactier Street Narrabeen;
  - 1214 Pittwater Road Narrabeen;
  - 1216 Pittwater Road Narrabeen (2 lots);
  - 1218 Pittwater Road Narrabeen;
  - 1220 Pittwater Road Narrabeen, strata with 7 units (1-7);
  - 1222 Pittwater Road Narrabeen;
  - 2 and 2a Goodwin Street Narrabeen;
- between Goodwin Street and Devitt Street (2 lots,2 lot addresses, 65 individual addresses):

[2] 1056 Pittwater Road formerly comprised Hob Nob Thai Restaurant (first floor) and Senses Hair and Beauty (ground floor). It is now part of Collaroy Services Beach Club, with the ground floor known as The Club House Function Room.

  - 1 Goodwin Street Narrabeen;
  - "Marquesas" (11 Ocean Street Narrabeen, strata) with 64 units (1-64)[3]
- between Narrabeen Street and King Street (2 lots,2 lot addresses, 11 individual addresses):
  - 81 Ocean Street Narrabeen, strata with 10 units (1-10);
  - 87 Ocean Street Narrabeen;
- between Albert Street and Waterloo Street (2 lots,2 lot addresses, 2 individual addresses):
  - 9 Albert Street Narrabeen;
  - 95 Ocean Street Narrabeen;
- between Waterloo Street and Wellington Street (4 lots,4 lot addresses, 27 individual addresses):
  - 105 and 107 Ocean Street Narrabeen;
  - 109 Ocean Street Narrabeen, strata with 24 units (1-24);
  - 2 Wellington Street Narrabeen;
- between Wellington Street and Albemarle Street (7 lots,7 lot addresses, 14 individual addresses):
  - 117 and 117a Ocean Street Narrabeen;
  - 119 Ocean Street Narrabeen, strata with 8 units (1-8);
  - 121, 123 and 125 Ocean Street Narrabeen;
  - 2 Albemarle Street Narrabeen;
- between Albemarle Street and Loftus Street (6 lots,6 lot addresses, 13 individual addresses):
  - 1 Albemarle Street Narrabeen, strata with 8 units (1-8);
  - 133, 135, 137 and 139 Ocean Street Narrabeen;
  - 2 Loftus Street Narrabeen;
- between Loftus Street and Octavia Street (8 lots,8 lot addresses, 32 individual addresses):
  - 145 Ocean Street Narrabeen;
  - 147 Ocean Street Narrabeen, strata with 3 units (1, 3 and 4);
  - 149 Ocean Street Narrabeen, strata with 12 units (1-12);
  - 151 Ocean Street Narrabeen;
  - 153a Ocean Street Narrabeen;
  - 155 Ocean Street Narrabeen;
  - 157 Ocean Street Narrabeen, strata with 12 units (1-12);
  - 2 Octavia Street Narrabeen;
- between Octavia Street and Tourmaline Street (8 lots,8 lot addresses, 16 individual addresses):
  - 159a Ocean Street Narrabeen;
  - 161 and 163 Ocean Street Narrabeen;
  - 165 Ocean Street Narrabeen, strata with 2 units (1-2);
  - 167 Ocean Street Narrabeen;
  - 169 Ocean Street Narrabeen, strata with 8 units (1-8);
  - 171 Ocean Street Narrabeen;
  - 2 Tourmaline Street Narrabeen;
- between Tourmaline Street and Emerald Street (7 lots,7 lot addresses, 37 individual addresses):
  - 1 Tourmaline Street Narrabeen, strata with 9 units (1-9);
  - 179 Ocean Street Narrabeen, strata with 12 units (1-12);
  - 181 Ocean Street Narrabeen, strata with 12 units (1-12);
  - 183, 185, 189 (vacant lot) and 191 Ocean Street Narrabeen;
- between Emerald Street and Malcolm Street (3 lots,3 lot addresses, 3 individual addresses):

[3] With 32 units (1-32) in the south-eastern tower and 32 units (33-64) in the north-western tower.

- 1 Emerald Street Narrabeen;
- 195a and 197 Ocean Street Narrabeen.

E2.2 Non-Beachfront Properties

Moving south to north, the 53 non-beachfront addresses in the study area were as follows (private section plan development unless stated as strata):

- between Collaroy Street and Fielding Street (4 lots, 1 lot address, 1 individual address):
  - Surf Rock Hotel (1060-1066 Pittwater Road, 4 lots) immediately landward of Collaroy Services Beach Club;
- between Frazer Street and Ramsay Street (1 lot, 1 lot address, 2 individual addresses):
  - 1110 Pittwater Road Collaroy, strata with 2 units (1-2);
- between Clarke Street and Mactier Street (1 lot, 1 lot address, 2 individual addresses):
  - 1206 Pittwater Road Collaroy, strata with 2 units (1-2);
- between Mactier Street and Goodwin Street (4 lots, 4 lot addresses, 4 individual addresses):
  - 1210 Pittwater Road Collaroy;
  - 4 Goodwin Street Narrabeen;
  - 1224 and 1226 Pittwater Road Narrabeen;
- between Goodwin Street and Devitt Street (4 lots,4 lot addresses, 4 individual addresses):
  - 5 Goodwin Street Narrabeen;
  - 1228 Pittwater Road Narrabeen;
  - 9 Ocean Street Narrabeen;
  - 23 Ocean Street Narrabeen;
- between Albert Street and Waterloo Street (2 lots,2 lot addresses, 2 individual addresses):
  - 7 Albert Street Narrabeen;
  - 4 Waterloo Street Narrabeen;
- between Waterloo Street and Wellington Street (3 lots,3 lot addresses, 3 individual addresses):
  - 3 and 5 Waterloo Street Narrabeen;
  - 4 Wellington Street Narrabeen;
- between Wellington Street and Albemarle Street (2 lots,2 lot addresses, 15 individual addresses):
  - 115 Ocean Street Narrabeen, strata with 13 units (1-13);
  - 127 Ocean Street Narrabeen, strata with 2 units (127 and 127a);
- between Albemarle Street and Loftus Street (5 lots,5 lot addresses, 10 individual addresses):
  - 129 Ocean Street Narrabeen, strata with 6 units (1-6);
  - 131 Ocean Street Narrabeen;
  - 4 Loftus Street Narrabeen;
  - 141 and 143 Ocean Street Narrabeen;
- between Octavia Street and Tourmaline Street (1 lots,1 lot address, 1 individual address):
  - 173 Ocean Street Narrabeen;
- between Emerald Street and Malcolm Street (6 lots,4 lot addresses, 9 individual addresses):
  - 193 Ocean Street Narrabeen, strata with 2 units (1-2);
  - 203 Ocean Street Narrabeen, strata with 5 units (1-5);
  - 205 Ocean Street Narrabeen;
  - 209-211 Ocean Street Narrabeen (3 lots).

E2.3 Other Properties

Note that the addresses located seaward of Pittwater Road or Ocean Street that were not included in the study area comprised (moving south to north):

- 91 and 93 Ocean Street Narrabeen;
- 97 Ocean Street Narrabeen (strata, with 4 units1-4);
- 99 Ocean Street Narrabeen;
- 7 and 9 Waterloo Street Narrabeen;
- 103 and 111 Ocean Street Narrabeen;
- 6 Wellington Street Narrabeen; and
- 153, 159, 175, 177 and 195 Ocean Street Narrabeen.

E3. FISHERMANS BEACH

Moving south to north, the 14 beachfront addresses in the study area at Fishermans Beach were as follows (private section plan development unless stated as strata):

- 1a, 1b, 1c, 1d, 1-3, 5, 7, and 11 Seaview Parade Collaroy;
- 1 and 3 Ocean Grove Collaroy;
- 1/9, 2/9 and 8 Florence Avenue Collaroy (with 9 Florence Avenue being a strata development); and
- 29 Beach Road Collaroy.

There were 15 private residential lots having beach frontage in the study area at Fishermans Beach, comprising 13 lot addresses[4].

Moving south to north, the 4 non-beachfront addresses in the study area were as follows (private section plan development unless stated as strata):

- 5 Ocean Grove Collaroy;
- 7 and 5 Florence Avenue Collaroy; and
- 6 Florence Ave Collaroy.

[4] 29 Beach Road Collaroy comprised 2 lots in the GIS data provided by Council (it is now understood to be one lot), and 1-3 Seaview Parade Collaroy also comprised 2 lots.

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Appendix F: Ecology of Collaroy-Narrabeen Beach and Fishermans Beach

CONTENTS

F1 ECOLOGY OF STUDY AREA

F1.1 Introduction

In this Appendix, a concise description of the ecology of Collaroy–Narrabeen and Fishermans Beach, including potential threats to biodiversity values, is provided. This was based on information provided by Eco Logical Australia Pty Ltd.

F1.2 Landscape Components

Collaroy – Narrabeen Beach and Fishermans Beach comprise the following natural landscape components:

- Long Reef Headland at the southern end of Fishermans Beach, consisting of outcropping Narrabeen Group shales and surrounded by a broad intertidal rock platform protected as an Aquatic Reserve under the *Fisheries Management Act 1994*;
- Fishermans Beach immediately north of Long Reef Headland, a short curving beach relatively sheltered to waves from the south by the headland;
- an exposed stretch of ocean beach extending northwards from near Collaroy SLSC to the entrance of Narrabeen Lagoon including vegetated dune areas established on the landward edge of the beach just north of Collaroy Services Beach Club and on the northern two thirds of the beach north of Devitt Street; and
- the Narrabeen Lagoon entrance which periodically closes with sand for extended periods.

F1.3 Vegetation Types and Broad Condition

F1.3.1 Preamble

Much of the dune system along Collaroy–Narrabeen Beach and Fishermans Beach has been covered by development, with the vegetated foredune remaining only within a series of fenced dune areas (or bays) between beach accessways at some locations. Four vegetated dune areas are located adjacent to the public car park north of Collaroy Services Beach Club, and 34 vegetated dune areas extend approximately 2 km northwards from Devitt Street to the entrance of Narrabeen Lagoon (Figure F1). There is more limited dune vegetation at Fishermans Beach, with no fenced areas.

The native vegetation within the dune bays is consistent with a Coastal Wattle Heath vegetation community (see Section F1.3.2) grading into a Spinifex Grassland vegetation community (see Section F1.3.3) on the seaward edge of the foredune, as mapped and described by Smith and Smith (2005a).

Collaroy – Narrabeen and Fishermans Beach has been mapped as a wildlife corridor in Smith and Smith (2005b) which is a general vegetation linkage along the Warringah coastline and around the edge of coastal lagoons.

Figure F1: Location of main vegetated dune areas at Collaroy-Narrabeen Beach

F1.3.2 Coastal Wattle Heath

Coastal Wattle Heath is an open-heath or closed-heath dominated by *Acacia longifolia* subspecies *sophorae* (Coastal Wattle). Of the other species in the community, the most common are *Banksia integrifolia* (Coastal Banksia), *Carpobrotus glaucescens* (Pigface), *Correa alba*, *Cynodon dactylon* (Couch, possibly introduced), *Hibbertia scandens*, *Isolepis nodosa*, *Leptospermum laevigatum* (Coastal Tea-tree), *Leucopogon parviflorus*, *Scaevola calendulacea* (Dune Fan-flower), *Spinifex sericeus* (Hairy Spinifex) and *Zoysia macrantha*.

This community occurs on foredunes landward of coastal beaches, on the landward side of the Spinifex Grassland community. It is widespread along the Warringah coastline, but absent from some beaches. Restoration of the community has occurred at many sites in Warringah and elsewhere around Sydney in recent decades through dune rehabilitation and stabilisation programs. As noted by Smith and Smith (2005b), the community supports one threatened plant species (*Chamaesyce psammogeton*), discussed further in Section F1.3.5.

F1.3.3 Spinifex Grassland

Spinifex Grassland is an open-grassland of *Spinifex sericeus* (Hairy Spinifex), with scattered low clumps of Coastal Wattle. The most common of the few other species in the community are *Actites megalocarpus* (Dune Thistle) and Dune Fan-flower. The community occurs on the unstable sands on the seaward edge of the foredune landward of coastal beaches. In Warringah, it has suffered in the past from heavy recreational use of the beaches, but has returned in recent decades as a result of dune rehabilitation and revegetation works (Smith and Smith 2005a).

F1.3.4 Weeds

All vegetated dune bays in the study area contain a mixture of native and weedy vegetation. The more disturbed dune bays tend to be the smaller and narrower ones where weed density is generally greatest at the landward interface with public open space or private property.

A 1943 aerial photograph shows the entire stretch of dune system in the study area almost devoid of vegetation, with numerous open sandy areas. The fact that the dunes have been wholly reconstructed since 1943, in particular following the intense 1974 storms, may contribute to the current disturbed condition of the vegetation in some of the dune areas.

A long-term annual targeted herbicide spraying program carried out in Winter has reduced numbers of the highly invasive coastal weed *Chrysanthemoides monilifera* subspecies *rotundata* (Bitou Bush) to low levels. Dominant weed species within the dune vegetation include *Gazania rigens* (Gazania), *Hydrocotyle bonariensis* (Pennywort), *Asparagus aethiopicus* (Asparagus Fern), *Acetosa sagittata* (Turkey Rhubarb) and *Lantana camara* (Lantana). Throughout the dune vegetation there are a number of bare sand patches or “blow-outs” formed by stormwater discharge and other effects.

Council is currently undertaking weed control and restoration works at three locations on Collaroy-Narrabeen and Fishermans Beach, namely within the dune bays at Collaroy SLSC and North Narrabeen SLSC, and at The Gardens Reserve at Narrabeen. The dune areas containing vegetation in the best condition with highest native species diversity and a mosaic of vegetation density and structure are located at The Gardens Reserve where Council has carried out an ongoing revegetation and restoration program since 2004, along with the larger dune bays near North Narrabeen SLSC. There are few areas of dune vegetation in very poor condition, but most of the vegetation is in moderate condition and could be readily restored to moderate – high condition through ongoing weed control and supplementary planting.

F1.3.5 Chamaesyce psammogeton (Sand Spurge)

A population of the threatened plant *Chamaesyce psammogeton* (Sand Spurge), classified as endangered under the NSW *Threatened Species Conservation Act 1995*, is the only threatened plant species known to occur in the study area. It is a small prostrate herb which is uncommon on sand dunes near the sea occurring sporadically north from Jervis Bay on unstable sands. Formerly regarded as widespread, it was in 1991 noted as being at risk of extinction (Carolin and Clarke, 1991).

Sand Spurge is threatened by excessive trampling due to its small size and prostrate growth habit. It appears that although the plant is short-lived it has a soil seed-bank that remains viable within a desiccated sand-dune environment for many years.

In 2004, a population of greater than 100 individuals was recorded in the dune bays at The Gardens Reserve by a bush-regeneration company undertaking a dune restoration and revegetation program. In 2009, a survey carried out by Warringah Council biodiversity staff in the same area recorded 89 plants and in February 2011, two plants. Populations of Sand Spurge may be dynamic over time, existing as seedbank in the dune system, regenerating in relatively large numbers after disturbance (such as weed control works) with plants dying out over a short period.

It is likely that the entire dune bay area of The Gardens Reserve is habitat for Sand Spurge. Habitat may also be present, in the form of a seed-bank, in the dune vegetation which extends northwards from the Gardens Reserve to the entrance of Narrabeen Lagoon. This is supported by two early records in 1912 and 1942 of Sand Spurge within 100m of The Gardens Reserve, although the exact location of these records may be inaccurate by as much as 1,000m.

Consultation with botanists from the Sydney Royal Botanic Gardens and a coastal dune vegetation expert suggests that while a soil seed-bank within the dunes may contain seeds of this species there is no way to determine the presence/absence of the plant in the soil seed-bank unless a disturbance event was simulated which stimulated germination.

F1.4 Fauna Habitat

The dune vegetation provides foraging and shelter habitat for small bird and reptile species. Small bird activity can be particularly high in the dense shrubby areas.

A large part of Long Reef Aquatic Reserve provides important foraging and roosting habitat for many shorebirds protected as migratory species under both the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and as threatened species under the NSW *Threatened Species Conservation Act 1995*. The many recorded numbers of these species is highly significant in the Sydney region, particularly as other important shorebird habitat areas in Sydney have suffered from increased disturbance and/or habitat loss (Straw, 2005).

The entrance of Narrabeen Lagoon and sandy beach environment of Collaroy–Narrabeen Beach and Fishermans Beach also provides potentially suitable foraging habitat for shorebirds such as the endangered Pied Oystercatcher (*Haematopus longirostris*) and, to a lesser extent, the vulnerable

Sooty Oystercatcher (*Haematopus fuliginosus*) and the vulnerable migratory Sanderling (*Calidris alba*).

Potential breeding habitat for the endangered migratory Little Tern (*Sterna albifrons*), the critically endangered Beach Stone-curlew (*Esacus neglectus*) and roosting habitat for the vulnerable migratory Sanderling may be found in the dune system at The Gardens Reserve and northwards to the entrance of Narrabeen Lagoon. However, this habitat is highly unlikely to be utilised due to heavy recreational usage on the beach, particularly during the spring-summer breeding season for these birds.

An endangered population of Little Penguin (*Eudyptula minor novaehollandiae*) occurs about 9km south of the study area at Manly, and about 19km north of the study area at Lion Island. Any penguins swimming offshore of the study area could be from either the Manly or Lion Island breeding populations, but the penguins are unlikely to come ashore unless sick or injured.

F1.5 Potential Threats to Habitat Values

Potential threats to the habitat values of Collaroy–Narrabeen Beach and Fishermans Beach include:

- loss of habitat for the endangered Sand Spurge and other flora and fauna species through the erosion of the dunes resulting from storms or other disturbance events;
- degradation of dune vegetation from rabbit activity and prolific weed invasion in particular the highly invasive coastal weed Bitou Bush; and
- disturbance to shorebirds foraging and roosting on the Long-Reef intertidal rock platform and foraging on intertidal areas of the beach from recreational use (although it is acknowledged that this threat is difficult to manage on the beach given the high usage by the surrounding large urban population).

F1.6 Recommendations to Protect Areas with Important Habitat/Biodiversity Values

The following actions are recommended to protect areas with important habitat/biodiversity values:

- continue the implementation of dune maintenance works including repair of fencing and walkways, stabilisation of blow-outs, ongoing targeted Bitou Bush control and effective rabbit control;
- in consultation with the Sydney Royal Botanic Gardens prepare and implement a threatened species management plan for the known population of Sand Spurge; and
- prepare a biodiversity management plan for the dune vegetation which addresses ongoing management including weed control and replacement/replenishment planting, monitoring and maintenance of vegetation structure and species diversity for small bird habitat.

Examples of areas that could be targeted for restoration of dune vegetation include (moving north to south) at and immediately north of Emerald Street, at and immediately north of Tourmaline Street (although stormwater discharge may make this problematic), immediately south of Albemarle Street, immediately north of Wellington Street, and immediately north of Waterloo Street (see Figure F2).

Figure F2: Examples of areas that could be targeted for restoration of dune vegetation at Narrabeen Beach

Advice should also be distributed to relevant Council staff that any works involving disturbance to dune vegetation should ensure that:

- areas directly and indirectly impacted are kept to a minimum;
- sand removal and deposition works within potential habitat for Sand Spurge are undertaken in accordance with guidelines to protect a Sand Spurge soil seedbank and to trigger germination at a recipient site;
- major works occur outside the small bird breeding period (spring); and
- disturbance is minimised to shorebirds foraging or roosting on the Long Reef rock platform and intertidal areas on the beach and Narrabeen Lagoon entrance by ensuring major works are timed outside the migratory shorebird visitation period (late Spring and Summer) and through ongoing public education and enforcement of bans on dogs on beaches and marine invertebrate collection on Long Reef Aquatic Reserve.

Appendix G:
Photographs of Stormwater Outlets

CONTENTS

G1. INTRODUCTION

In this Appendix, photographs are provided of stormwater outlets in the study area, progressing north to south.

A Tideflex 'duckbill' check valve was installed on the stormwater outlet near Frazer Street at Collaroy in August 2013 (Figure G14). This was installed with the intent of preventing beach sand from entering the stormwater pipe and was designed to operate even when partially buried with sand. A raised stainless steel grate was to be installed on the pit immediately upstream of this outlet, to facilitate surcharging when the outlet is buried and the valve cannot open. The overall aim of these works was to alleviate local flooding problems being experienced in Pittwater Road in this area. The performance of the valve was to be monitored and other beach outlets are under consideration for similar treatment in the future (Ian Campbell, Stormwater Investigations Engineer, Warringah Council, personal communication).

In Figure G25, the blacked ribbed "structure" adjacent to the stormwater outlet is a footing for a sign that was to be installed. Council has been installing signage on outlets stating "Danger, Keep Clear, Stormwater Pipes" (Dean McNatty, Stormwater Assets Engineer, Warringah Council, personal communication).

G2. PHOTOGRAPHS

Figure G1: Stormwater outlet near car park south of Malcolm Street at Narrabeen, 20 April 2013

Figure G2: Stormwater outlet near car park south of Malcolm Street after erosion, 25 June 2013

Figure G3: Scour at stormwater outlet near Tourmaline Street at Narrabeen, 20 April 2013

Figure G4: Closer view of stormwater outlet and scour near Tourmaline Street, 20 April 2013

Figure G5: Stormwater outlet near Tourmaline Street, 2 April 2013

Figure G6: Area (near top of walkway) containing stormwater soakage pits near Octavia Street at Narrabeen, 14 February 2009

Figure G7: Stormwater outlet near Albert Street at Narrabeen (obscured by vegetation), 8 December 2013

Figure G8: Stormwater pipe near Goodwin Street at Narrabeen, 22 December 2008

Figure G9: Stormwater pipe near Ramsay Street at Collaroy, 10 June 2007

Figure G10: Stormwater pipe near Ramsay Street, 10 June 2007, looking north

Figure G11: Stormwater pipe near Ramsay Street, 22 December 2008

Figure G12: Stormwater outlet near Frazer Street at Narrabeen, 10 June 2007

Figure G13: Stormwater outlet near Frazer Street, 27 February 2009

Figure G14: Tideflex 'duckbill' check valve fitted to Frazer Street outlet, 22 August 2013

Figure G15: Collaroy Street stormwater outfall at Collaroy Beach, 10 June 2007

Figure G16: Collaroy Street stormwater outfall at Collaroy Beach, 27 February 2009

Figure G17: Excavation surrounding the Collaroy Street outfall as part of investigations for proposed reconstruction works, 14 November 2013

Figure G18: Stormwater outlet adjacent to rock baths at southern end of Collaroy Beach, 27 February 2009

Figure G19: Stormwater outlet near Fox Park at Fishermans Beach, 2 November 2008

Figure G20: Stormwater outlet near Fox Park at Fishermans Beach, 25 February 2011

Figure G21: Stormwater pipe near Florence Avenue at Fishermans Beach, 8 December 2013

Figure G22: Stormwater outlet near Ocean Grove at Fishermans Beach, 28 February 2009

Figure G23: Stormwater pipe near Anzac Avenue at Fishermans Beach, 10 June 2007

Figure G24: Stormwater pipe near Anzac Avenue at Fishermans Beach, 28 February 2009

Figure G25: Stormwater pipe near Anzac Avenue at Fishermans Beach, 8 December 2013

Figure G26: Stormwater outlet located about 40m west of boat ramp at Fishermans Beach, 28 February 2009

Figure G27: Minor stormwater outlet (circled) at Warringah Surf Rescue building at Fishermans Beach, 28 February 2009

Appendix H:
Legislative and Planning Context

CONTENTS

H1. INTRODUCTION

In this Appendix, key legislation and associated guidelines are described.

H2. DOCUMENTS

H2.1 Guidelines for Preparing CZMPs

The document *Guidelines for Preparing Coastal Zone Management Plans* (OEH, 2013b) was gazetted in the *Government Gazette of the State of New South Wales* dated 19 July 2013 as:

- a manual relating to the management of the coastline pursuant to section 733(5)(b) of the *Local Government Act 1993* (as notified by Brad Hazzard, Minister for Planning and Infrastructure); and,
- Minister's guidelines for the purposes of preparing draft coastal zone management plans pursuant to section 55D of the *Coastal Protection Act 1979* (as notified by Robyn Parker, Minister for the Environment).

H2.2 *NSW Coastal Policy 1997*

The *NSW Coastal Policy 1997* (NSW Government, 1997) is based on two fundamental principles, namely ecologically sustainable development and integrated coastal zone management. It is structured in a framework of 9 main "goals" and 9 main "objectives".

Each objective is met with a number of 'strategic actions' which were assigned to local governments and state government departments and agencies as appropriate. These include the consideration of CZMPs in the preparation of LEPs and DCPs.

It is noted in Department of Planning (2009b) that "The Minister for Planning has issued a Direction under section 117 of the *Environmental Planning and Assessment Act 1979* to all local councils in the coastal zone regarding the *NSW Coastal Policy 1997*. In preparing a draft local environmental plan (LEP), councils are required to include provisions that give effect to and are consistent with the Coastal Policy, unless the inconsistency is justified by an environmental study or strategy".

H2.3 NSW Coastal Planning Guideline

The *NSW Coastal Planning Guideline* (Department of Planning, 2010a) was prepared to provide guidance on how sea level rise was to be incorporated into land use planning and development assessment in coastal areas. The guideline was based on the implementation of six coastal planning principles for consideration of sea level rise, namely:

1. assess and evaluate coastal risks taking into account the sea level rise planning benchmarks[1];
2. advise the public of coastal risks to ensure that informed land use planning and development decision making can occur;
3. avoid intensifying land use in coastal risk areas through appropriate strategic and land use planning;
4. consider options to reduce land use intensity in coastal risk areas where feasible;
5. minimise exposure of development to coastal risks; and
6. implement appropriate management responses and adaptation strategies.

[1] "Sea level rise planning benchmarks" was referring to the now repealed *NSW Sea Level Rise Policy Statement* (which is no longer NSW Government policy), and should be replaced with "Council's adopted sea level rise projections".

H2.4 Plans of Management

H2.4.1 Preamble

There are two plans of management that apply to the study area. These comprise the *Coastal Lands Plan of Management* (adopted 24 September 2002) and *Griffith Park Plan of Management* (adopted 22 February 2011), as discussed in Section H2.4.2 and H2.4.3 respectively.

H2.4.2 Coastal Lands

The *Coastal Lands Plan of Management* provides the framework for managing the coastal open space of Warringah, which comprises both Community Land and Crown Lands. In this, land classifications were as follows:

- dune and beach areas in the study area were 'Natural Area: Foreshore'[2];
- foreshore reserve areas at North Narrabeen, between Albert Street and Devitt Street and north and south of Collaroy Beach Services Beach Club were 'Park'; and
- surf clubs were 'General Community Use'.

The *Coastal Lands Plan of Management* contains a number of management actions that are relevant to coastal management in the study area including:

- develop and implement a four-year program of dune maintenance;
- monitor coastal stability/hazards;
- in respect of the *Collaroy Narrabeen Coastline Management Plan* (Warringah Council, 1997) the *Coastal Lands Plan of Management* specifically authorises:
  - any works required to implement any part of the Plan;
  - the granting of any easements or the acquisition of easements in order to facilitate any works or the maintenance of any works under the Plan; and,
  - the imposition or acquisition of any Positive or Restrictive Covenants which may be necessary.
- embellish & maintain areas of open space acquired along Collaroy/Narrabeen and Fishermans Beach as shown on concept plans; and,
- ensure there are well maintained and appropriate regulatory and information signs provided at key locations including dune protection areas.

H2.4.3 Griffith Park

Griffith Park was proclaimed as a Crown Reserve in 1914 and in 1995 Warringah Council was appointed reserve trust manager with the responsibility for care, control and management of the reserve. In the *Griffith Park Plan of Management*, Council's plans for management of the park are outlined, which includes the southern portion of Fishermans Beach (south of Anzac Avenue) and Long Reef Headland.

The *Griffith Park Plan of Management* contains a number of actions that are specific to management of Fishermans Beach including:

[2] Except note that Fishermans Beach south of Anzac Avenue was covered by the *Griffith Park Plan of Management* (Section H2.4.3).

- continue to monitor environmental quality and reduce erosion from stormwater drainage at Fishermans Beach;
- maintain public education in heritage protection, including brochures and interpretive signage at Fishermans Beach and key locations around the Coastal Walk;
- improve shade and shelter opportunities for large groups, particularly within the Fishermans Beach area;
- review opportunities for improving management of large groups/buses visiting Fishermans Beach/rock platform areas in consultation with DECCW (Aquatic Protected Areas Section), with the aim of formalising bookings for large groups; and,
- implementation of Stormwater Rationalisation Plan Stage 2, including further diversion of stormwater flows from the Fishermans Beach outlets to the Long Reef Golf Course wetland areas.

H2.5 Warringah Development Control Plan 2011

Part E9 of the *Warringah Development Control Plan 2011* (denoted as "DCP 2011" herein) is relevant to coastal hazards. In this, it is stated that:

- "the risk of damage from coastal processes is to be reduced through having appropriate setbacks and foundations, as detailed in Criteria for the Siting and Design of Foundations for Residential Development" (Geomarine, 1991); and
- "The applicant must demonstrate compliance with the Collaroy Narrabeen Coastline Management Plan".

H3. LEGISLATION

H3.1 *Coastal Protection Act 1979*

The *Coastal Protection Act 1979* is administered by the NSW Office of Environment and Heritage (OEH). The broad objectives of the *Coastal Protection Act 1979* are to make provisions relating to the use and occupation of coastal regions whilst encouraging sustainable use of these areas, and the facilitation of certain coastal protection works.

In Part 4A (Sections 55A to 55L) of the *Coastal Protection Act 1979*, information is given on various issues relating to CZMP's, including matters to be dealt with, public consultation, certification, gazettal, amendment, availability and breaches.

In Section 55M of the *Coastal Protection Act 1979*, preconditions for the granting of development consent relating to coastal protection works under the *Environmental Planning and Assessment Act 1979* are described.

H3.2 *Environmental Planning and Assessment Act 1979*

H3.2.1 General

The *Environmental Planning and Assessment Act 1979* is the primary legislation for planning and land use within NSW.

In Part 3 of the *Environmental Planning and Assessment Act 1979*, key environmental planning instruments for use by the NSW Government and local councils are established. These comprise State Environmental Planning Policies (SEPPs), Local Environmental Plans (LEPs) and Development Control Plans (DCPs). Also, the process for lodgement and assessment of development applications is described in the Act.

In Part 4 of the *Environmental Planning and Assessment Act 1979*, development that requires consent by a consent authority (typically Council) is described. Section 79C outlines matters for consideration when evaluating a development application, which include planning instruments (SEPPs, LEPs and DCPs) and CZMPs. Section 79C(1) is reproduced below:

> "In determining a development application, a consent authority is to take into consideration such of the following matters as are of relevance to the development the subject of the development application:
>
> (a) the provisions of:
> - (i) any environmental planning instrument, and
> - (ii) any proposed instrument that is or has been the subject of public consultation under this Act and that has been notified to the consent authority (unless the Director-General has notified the consent authority that the making of the proposed instrument has been deferred indefinitely or has not been approved), and
> - (iii) any development control plan, and
> - (iiia) any planning agreement that has been entered into under section 93F, or any draft planning agreement that a developer has offered to enter into under section 93F, and

(iv) the regulations (to the extent that they prescribe matters for the purposes of this paragraph), and
(v) any coastal zone management plan (within the meaning of the *Coastal Protection Act 1979*),

that apply to the land to which the development application relates,

(b) the likely impacts of that development, including environmental impacts on both the natural and built environments, and social and economic impacts in the locality,
(c) the suitability of the site for the development,
(d) any submissions made in accordance with this Act or the regulations,
(e) the public interest".

Part 5 of the *Environmental Planning and Assessment Act 1979* relates to activities that are permissible without consent under Part 4 but require approval from a Minister or Public Authority, or are proposed to be carried out by a Minister or Public Authority (such as a Council).

H3.2.2 Section 149 Certificates

Under Section 149 of the *Environmental Planning and Assessment Act 1979*, Council is obliged to issue a planning certificate (known as a "Section 149 Certificate") to notify property owners about matters affecting their land. This may be requested at any time by a property owner but is typically requested when a property is redeveloped or sold. When land is bought or sold, the *Conveyancing Act 1919* requires that a Section 149 Certificate be attached to the Contract for Sale.

There are two types of planning certificates that can be issued by Council, namely under Section 149(2) or Section 149(5) of the *Environmental Planning and Assessment Act 1979*. A planning certificate issued under Section 149(2) provides information about the zoning of the property, the relevant state and local planning controls and various other property affectations. The matters addressed by Section 149(2) certificates are governed by Schedule 4 of the *Environmental Planning and Assessment Regulation 2000*.

A draft planning circular "Coastal hazard notations on Section 149 planning certificates" was released for public exhibition by the NSW Department of Planning & Infrastructure on 30 January 2014.

H3.3 *Local Government Act 1993*

Provisions in this legislation that are relevant to the implementation and funding of coastal management activities include:

- Section 495 – allows councils to levy 'special rates' on rateable land that benefits from council services other than domestic waste management services;
- Sections 496B and 553B – allows an annual levy to be charged on rateable land benefitting from the provision of 'coastal protection services' by councils defined as maintenance and repair of coastal protection works and managing the impacts of these works; and,
- Section 733(2), exemption of a Council from liability in respect of the likelihood of land in the coastal zone being affected by a coastline hazard or the nature or extent of any such hazard.

H3.4 *Crown Lands Act 1989*

The area contains areas of Crown Land that are not within Council's land register, and also Crown Land that is under the care and management of Council. The *Crown Lands Act 1989* governs how Crown Land is to be managed based on a number of principles as per Section 11 of the Act, which include that:

- environmental protection principles be observed;
- natural resources be conserved wherever possible (including water, soil, flora, fauna and scenic quality);
- public use and enjoyment, and multiple use (where appropriate) be encouraged;
- it is used and managed in such a way that the land and its resources are sustained in perpetuity; and
- it be occupied, sold, or otherwise dealt with in the best interests of the State consistent with these principles.

H3.5 *State Environmental Planning Policy No.71 - Coastal Protection*

State Environmental Planning Policy No. 71 – Coastal Protection (denoted as "SEPP 71" herein) is the main SEPP applying to development within the coastal zone of NSW. The coastal zone is defined on maps by the NSW Government and includes the study area, as indicated on the Greater Metropolitan Region Maps No.13 and No.14. Within these coastal zones a 'sensitive coastal location' is defined in SEPP 71 as land within:

- 100 metres above mean high water mark of the sea, a bay or an estuary;
- a coastal lake, or within 100m of the water's edge of a coastal lake;
- a declared Ramsar Wetland, or within 100m of a declared Ramsar Wetland;
- a declared World Heritage Property, or within 100m of a declared World Heritage Property;
- a declared aquatic reserve under the *Fisheries Management Act 1994*, or within 100m of a declared aquatic reserve;
- a declared marine park under the *Marine Parks Act 1997*, or within 100m of a declared marine park;
- within 100m of land reserved or dedicated under the *National Parks and Wildlife Act 1974*;
- within 100m of SEPP 14 Coastal Wetlands; and
- residential land within 100m of SEPP 26 Littoral Rainforests.

In Clause 8 of SEPP 71, matters that are to be taken into consideration when councils are preparing an LEP or determining a development application are listed. These include:

- retaining, improving or providing new public access to coastal foreshore areas;
- aesthetic impacts of development on the surrounding area;
- public amenity impacts of development on the coastal foreshore;
- fauna and flora conservation;
- protection of wildlife corridors;
- impacts of coastal processes and hazards on the development and any likely impacts of development on coastal processes and hazards;
- impacts on water quality;
- reducing conflict between land and water based activities; and
- protection of heritage features.

H3.6 *State Environmental Planning Policy (Infrastructure) 2007*

Division 25 of *State Environmental Planning Policy (Infrastructure) 2007* (denoted as “SEPP Infrastructure” herein) relates to waterway or foreshore management activities, including:

- coastal management and beach nourishment, including erosion control, dune or foreshore stabilisation works, headland management, weed management, revegetation activities and foreshore access ways; and,
- coastal protection works.

In SEPP Infrastructure, the types of development that are permitted without and with consent are described in Clauses 129 and 129A respectively. Clause 129 applies to public authorities (such as a Council). Clause 129A is reproduced below:

129A Development with consent

(1) Development for the purposes of a sea wall or beach nourishment may be carried out by any person with consent on the open coast or entrance to a coastal lake.
(2) If a coastal zone management plan does not apply to the land on which any such development is to be carried out, the Coastal Panel has the function of determining a development application for development to which this clause applies.
(3) Before determining a development application for development to which this clause applies, the consent authority must take the following matters into consideration:
    (a) the provisions of any coastal zone management plan applying to the land,
    (b) the matters set out in clause 8 of State Environmental Planning Policy No 71—Coastal Protection,
    (c) any guidelines for assessing and managing the impacts of coastal protection works that are issued by the Director-General for the purposes of this clause and published in the Gazette

H3.7 *Warringah Local Environmental Plan 2011*

Clauses 5.5 and 6.5 of *Warringah Local Environment Plan 2011* (denoted as “LEP 2011” herein) are relevant to coastal hazards.

Clause 5.5 of LEP 2011 is reproduced below:

(1) The objectives of this clause are as follows:
    (a) to provide for the protection of the coastal environment of the State for the benefit of both present and future generations through promoting the principles of ecologically sustainable development,
    (b) to implement the principles in the NSW Coastal Policy, and in particular to:
        (i) protect, enhance, maintain and restore the coastal environment, its associated ecosystems, ecological processes and biological diversity and its water quality, and
        (ii) protect and preserve the natural, cultural, recreational and economic attributes of the NSW coast, and

(iii) provide opportunities for pedestrian public access to and along the coastal foreshore, and
(iv) recognise and accommodate coastal processes and climate change, and
(v) protect amenity and scenic quality, and
(vi) protect and preserve rock platforms, beach environments and beach amenity, and
(vii) protect and preserve native coastal vegetation, and
(viii) protect and preserve the marine environment, and
(ix) ensure that the type, bulk, scale and size of development is appropriate for the location and protects and improves the natural scenic quality of the surrounding area, and
(x) ensure that decisions in relation to new development consider the broader and cumulative impacts on the catchment, and
(xi) protect Aboriginal cultural places, values and customs, and
(xii) protect and preserve items of heritage, archaeological or historical significance.

(2) Development consent must not be granted to development on land that is wholly or partly within the coastal zone unless the consent authority has considered:
- (a) existing public access to and along the coastal foreshore for pedestrians (including persons with a disability) with a view to:
  - (i) maintaining existing public access and, where possible, improving that access, and
  - (ii) identifying opportunities for new public access, and
- (b) the suitability of the proposed development, its relationship with the surrounding area and its impact on the natural scenic quality, taking into account:
  - (i) the type of the proposed development and any associated land uses or activities (including compatibility of any land-based and water-based coastal activities), and
  - (ii) the location, and
  - (iii) the bulk, scale, size and overall built form design of any building or work involved, and
- (c) the impact of the proposed development on the amenity of the coastal foreshore including:
  - (i) any significant overshadowing of the coastal foreshore, and
  - (ii) any loss of views from a public place to the coastal foreshore, and
- (d) how the visual amenity and scenic qualities of the coast, including coastal headlands, can be protected, and
- (e) how biodiversity and ecosystems, including:
  - (i) native coastal vegetation and existing wildlife corridors, and
  - (ii) rock platforms, and
  - (iii) water quality of coastal waterbodies, and
  - (iv) native fauna and native flora, and their habitats

  can be conserved, and
- (f) the cumulative impacts of the proposed development and other development on the coastal catchment.

(3) Development consent must not be granted to development on land that is wholly or partly within the coastal zone unless the consent authority is satisfied that:
- (a) the proposed development will not impede or diminish, where practicable, the physical, land-based right of access of the public to or along the coastal foreshore, and

(b) if effluent from the development is disposed of by a non-reticulated system, it will not have a negative effect on the water quality of the sea, or any beach, estuary, coastal lake, coastal creek or other similar body of water, or a rock platform, and
(c) the proposed development will not discharge untreated stormwater into the sea, or any beach, estuary, coastal lake, coastal creek or other similar body of water, or a rock platform, and
(d) the proposed development will not:
  (i) be significantly affected by coastal hazards, or
  (ii) have a significant impact on coastal hazards, or
  (iii) increase the risk of coastal hazards in relation to any other land.

Clause 6.5 of LEP 2011 is reproduced below:

(1) The objectives of this clause are as follows:
  (a) to avoid significant adverse impacts from coastal hazards,
  (b) to enable evacuation of coastal risk areas in an emergency,
  (c) to ensure uses are compatible with coastal risks,
  (d) to preserve and protect Collaroy Beach, Narrabeen Beach and Fishermans Beach as national assets for public recreation and amenity.
(2) This clause applies to the land shown on the Coastline Hazard Map as:
  (a) Area of Wave Impact and Slope Adjustment, and
  (b) Area of Reduced Foundation Capacity.
(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:
  (a) will not significantly adversely affect coastal hazards, and
  (b) will not result in significant detrimental increases in coastal risks to other development or properties, and
  (c) will not significantly alter coastal hazards to the detriment of the environment, and
  (d) incorporates appropriate measures to manage risk to life from coastal risks, and
  (e) avoids or minimises exposure to coastal hazards, and
  (f) makes provision for relocation, modification or removal of the development to adapt to coastal hazards and NSW sea level rise planning benchmarks.
(4) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the foundations of the development have been designed to be constructed having regard to coastal risk.
(5) A word or expression used in this clause has the same meaning as it has in the NSW Coastal Planning Guidelines: Adapting to Sea Level Rise (ISBN 978-1-74263-035-9) published by the NSW Government in August 2010, unless it is otherwise defined in this Plan.

Appendix I:
Coastal Processes and Coastline Hazards

CONTENTS

I1. INTRODUCTION

In this Appendix, coastal processes and coastline hazards that apply in the study area are described in Section I2 and I3 respectively.

To meet the requirements of OEH (2013b), it is necessary to assess hazards for current and future conditions. As noted in OEH (2013b), these future conditions should include consideration of "Council's adopted sea level rise projections or a range of projections" (where "Councils should consider adopting projections that are widely accepted by competent scientific opinion"). However, the future planning periods and projections to use are not specified in OEH (2013b).

That stated, there is a requirement in OEH (2013b) to categorise property as in the Current hazard area, 2050 hazard area and 2100 hazard area, which makes it logical to choose 2050 and 2100 lines for mapping purposes. Therefore, to meet the requirements of OEH (2013b), Immediate, 2050 and 2100 Hazard Lines are defined herein.

Council advised that the sea level rise projections to adopt for the mapping herein were to be the same as in the *NSW Sea Level Rise Policy Statement* (DECCW, 2009b). That is, Council's adopted sea level rise projections are as per DECCW (2009b). However, the latest Intergovernmental Panel on Climate Change (2013a, b) sea level rise estimates, which were developed after the release of DECCW (2009b), were considered as part of a risk assessment in **Appendix L**.

In OEH (2013b) it is stated that the following coastline hazards should be identified as a minimum:

1. beach erosion: storm bite due to a beach erosion event with an average recurrence interval (ARI) of approximately 100 years plus an allowance for reduced building foundation capacity;
2. shoreline recession: estimated recession due to sediment budget deficit and projected sea level rise;
3. coastal lake or watercourse entrance instability: qualitative assessment of entrance dynamics based on historical records, for current conditions and projected future conditions;
4. coastal inundation (including estuaries): estimate of wave run-up level and overtopping of dunes resulting from an extreme ocean storm event, for current conditions and projected future conditions;
5. coastal cliff or slope instability: slope stability assessment; see Australian Geomechanics Society (2007), for current conditions and projected future conditions;
6. tidal inundation (including estuaries): estimate of areas inundated from still water levels with a 50 or 100-year ARI, for current conditions and projected future conditions;
7. erosion within estuaries caused by tidal waters, including the interaction of those waters with catchment floodwaters; and
8. estimate of estuary foreshore erosion due to physical processes and flood events.

For Item 1, note that hazard lines were defined including both the Zone of Reduced Foundation Capacity as specified by OEH (2013b), and also at the landward edge of the Zone of Slope Adjustment.

Items 3, 7 and 8 are not applicable to the study herein as no estuaries are included in the study area. Item 5 is not applicable as no rocky cliff/bluffs are included in the study area. As required by OEH (2013b), Items 1, 2, 4 and 6 have been considered herein. Item 6 is more relevant for estuaries, but has been considered as tides are a component of coastal inundation (Item 4).

I2. COASTAL PROCESSES

I2.1 Preamble

Large waves and elevated water levels associated with coastal storms can cause erosion of sandy beaches and wave runup levels that can overtop foreshore areas. A background on waves and water levels offshore of the study area is provided in Section I2.2 and Section I2.3 respectively. The combination of waves and water levels leads to wave runup as described in Section I2.4. A discussion on coastal storms in general is provided in Section I2.5.

In Section I2.6, the long term evolution of Warringah's coastline is described. Sediment transport processes are outlined in Section I2.7. Discussion on climate change is provided in Section I2.8.

I2.2 Waves

I2.2.1 Offshore Wave Climate

Kulmar et al (2005) predicted that the 100 year average recurrence interval (ARI) significant wave height (H_s)[1] exceeded for a duration of 1 hour and 6 hours offshore of Sydney was 9.5m and 8.5m respectively, about six times larger than the average H_s of 1.6m. Shand et al (2011) estimated a 100 year ARI 1 hour duration H_s of 9.0m offshore of Sydney. Note that offshore waves are typically measured in depths exceeding 80m.

Beach erosion and relatively large wave runup is strongly linked to the occurrence of high wave conditions with elevated ocean water levels, so erosion and runup are more likely to be significant when large waves coincide with a high tide. Therefore, a 6 hour duration is appropriate for adoption herein, as storms with a duration of 6 hours are likely (50% probability) to coincide with high tide on the NSW coast (which is a prerequisite for the elevated water level to occur). A 1 hour duration only has an 8% probability of coinciding with high tide.

Most storm waves (defined herein as H_s exceeding 3m) offshore of Sydney come from the south (48%), with about 26% coming from the south-south-east and 10% from the south-east. That is, 84% of storm waves come from the south to south-east octant (WorleyParsons, 2009).

The Sydney directional Waverider buoy data collected from 1992 to 2008 was analysed to determine (1 hour duration) 100 year ARI H_s and T_p (peak spectral wave period[2]) values from various offshore wave directions based on extreme value analysis, see Table I1[3]. Relative wave energy values are also listed in Table I1, with wave energy calculated as $H_s^2T_p^2$ and expressed relative to the maximum wave energy from the SSE direction being equal to unity. It is evident that offshore wave energy is concentrated into the SE, SSE and S directions, with 64% of the total offshore energy coming from these directions.

[1] The significant wave height is the average height of the highest one-third of the waves in a particular record.
[2] The peak spectral wave period is determined by the inverse of the frequency at which the wave energy spectrum reaches its maximum.
[3] Note that the T_p value associated with the extreme wave height is not the corresponding return value of T_p.

Table I1: 100 year ARI significant wave height (H_s), peak spectral wave period (T_p) and relative wave energy values for offshore of Sydney, for varying offshore wave directions

Direction	H_s (m)	T_p (s)	Relative wave energy
NE	4.4	9.2	0.11
ENE	6.0	10.7	0.27
E	7.0	11.6	0.43
ESE	7.3	11.8	0.48
SE	8.5	12.7	0.76
SSE	9.3	13.3	1.00
S	8.8	13.0	0.86
SSW	5.5	10.2	0.21

I2.2.2 Nearshore Wave Climate

As waves approach the shore, they may be transformed by the processes of refraction, shoaling, diffraction, attenuation, reflection and breaking. Therefore, the nearshore wave climate in the study area has a different wave height and particularly wave direction compared to offshore (with wave period generally remaining constant). Typically, waves break in a water depth about equal to the wave height.

The relative prominence (offshore extent) of the Long Reef headland provides some sheltering to Fishermans Beach and the southern end of Collaroy Beach from offshore storm waves coming from the dominant S to SE directions. Narrabeen and North Narrabeen are generally fully exposed to the offshore wave climate, but it is recognised that various offshore reefs cause complexities in wave transformation in the study area[4].

Based on modelling completed by WorleyParsons (2009), peak 100 year ARI wave heights reduce to about 75% of fully exposed values south of Fielding Street at Collaroy Beach, and to about 63% at Fishermans Beach (with the fully exposed values applying north of Stuart Street at Collaroy-Narrabeen Beach).

I2.3 Elevated Water Levels

The main factors which contribute to elevated ocean still water levels on the NSW coast comprise:

- astronomical tide;
- storm surge (barometric setup and wind setup); and,
- wave setup (caused by breaking waves).

Astronomical tide is the regular rise and fall of sea level in response to the gravitational attraction of the sun, moon and planets, and a rotational effect due to the spin of the earth on its axis. Tides along the NSW coastline are semi diurnal, with high and low water approximately equally spaced in time and occurring twice daily (that is, on average, there are two high tides and two low tides in any 24 hour period). There is also significant diurnal inequality in NSW coast tides, a difference in height of the two high waters or the two low waters of each tidal day.

[4] For example, there is a tendency for wave focussing (and rip formation) in the Wetherill Street to Devitt Street area for some wave directions (PWD, 1987).

Barometric setup is a localised vertical rise in the still water level due to a reduction in atmospheric pressure. The increase in water level is approximately 0.1m for each 10 hectopascal drop below normal barometric pressure of 1013 hPa (MHL, 1992). Wind setup is the vertical rise in the still water level on the downwind side of a body of water caused by wind stresses on the surface of the water.

Wave setup is defined as the superelevation of the mean water level caused by wave action alone. The phenomenon is related to the conversion of the kinetic energy of wave motion to quasi steady potential energy during wave breaking. It is manifested as a decrease in water level prior to breaking (with a maximum set down at the break point), and from the break point the mean water surface slopes upward to the point of intersection with the shore (Coastal Engineering Research Center, 1984).

Individual waves also cause temporary water level increases above the still water level due to the process of wave runup or uprush (see Section I2.4). Note that sea level is also predicted to rise due to climate change (the Greenhouse Effect). This is discussed further in Section I2.8.1.

In NSW, open coast still water levels (within the wave breaking zone) can increase by up to about 2m above normal levels in storms due to storm surge and wave setup, with components approximately as large as follows for a 100 year ARI event:

- storm surge of about 0.6m (barometric setup of up to about 0.3m to 0.4m, and wind setup of up to about 0.2m to 0.3m); and,
- wave setup of up to about 1.4m (typically about 10-15% of the breaking significant wave height).

This increase in water level is superimposed on the astronomical tide, which typically varies between about –1m AHD (Lowest Astronomical Tide) and 1m AHD (Highest Astronomical Tide) along the NSW coast (with 0m AHD close to mean sea level), and typical low and high tide levels being about -0.5m AHD and 0.5m AHD respectively)[5]. Various tidal planes are listed in Table I2[6].

Table I2: Approximate tidal planes in NSW

Tidal Plane	Water Level (m AHD)
Lowest Astronomical Tide	-1.0
Mean Low Water Springs	-0.6
Mean Low Water	-0.5
Mean Low Water Neaps	-0.4
Mean Sea Level	0.0
Mean High Water Neaps	0.4
Mean High Water	0.5
Mean High Water Springs	0.6
Highest Astronomical Tide	1.0

[5] Note that published predicted tidal information for NSW is generally reported to Chart Datum, rather than AHD. To convert predicted water levels from Chart Datum to AHD, subtract 0.925m for Sydney. For example, a reported predicted tidal level of 1.5m (relative to Chart Datum) represents a level of about 0.6m AHD.
[6] Spring tides occur twice per month (during new or full moons) and result in higher high tides and lower low tides (that is, a larger tidal range, compared to the average). Neap tides also occur twice per month (during quarter moons) and result in lower high tides and higher low tides (that is, a smaller tidal range, compared to the average). The height of the spring tide also varies throughout the year and due to the lunar Metonic cycle, the 18.6 period over which the moon returns to the same position relative to the earth (MHL, 1992).

Astronomical tide variation occurs independently of storm surge and wave setup, that is it is not affected by coastal storms. Astronomical tide levels are predictable and are routinely calculated years in advance of their occurrence. It is the anomalies (difference in measured water level compared to the predicted water level outside the breaker zone, mainly due to storm surge) and wave setup associated with coastal storms that are not so predictable in timing, although they can be forecast as a coastal storm develops.

Department of Environment, Climate Change and Water [DECCW] (2010b) has estimated that the 100 year ARI still water level offshore of Sydney (excluding wave setup) is 1.44m AHD at present. Including wave setup of 1.3m, calculated as 15% of the 100 year ARI H_s of 8.5m for a 6 hour duration estimated by Kulmar (2005)[7], the 100 year ARI water level at fully exposed shorelines landward of wave breaking is about 2.7m AHD[8]. At less exposed areas (such as the southern end of Collaroy Beach, and Fishermans Beach), equivalent elevated water levels would be reduced due to lower wave setup, namely to about 2.4m and 2.2m respectively.

It is not relevant to map tidal inundation in the study area as per Item 6 of OEH (2013b) from Section I1. This is because water levels of 2.2m to 2.7m AHD are contained within sandy beach areas of the study area, and do not extend landward to developed areas, and mapping these water levels on the beach would not be meaningful. That stated, these water levels may cause backwater effects in the stormwater system landward of sandy beaches in the study areas, which would require further investigations to assess (see Section 7 of main report).

I2.4 Wave Runup

Wave runup is site specific, but typically reaches a maximum level of about 8m AHD at beaches on the open NSW coast at present. Higgs and Nittim (1988) found that for a coastal storm that occurred in August 1986, maximum runup levels at Narrabeen Beach were about 7.3m AHD (near Clarke Street), with 4.4m AHD recorded near Fielding Street at Collaroy, and up to 5.3m AHD at Fishermans Beach, It is considered to be reasonable to adopt a 100 year ARI wave runup level of 8m AHD for exposed areas of Collaroy-Narrabeen Beach at present.

At the southern end of Collaroy Beach (south of Fielding Street) and at Fishermans Beach, equivalent runup levels would be lower (WorleyParsons, 2009). A wave runup level of 6m AHD was adopted at these locations.

However, note that the above runup levels would only be realised if the foreshore was at the runup height or higher. If the foreshore was lower, the runup would 'fold over' the foreshore crest level and travel as a bore for a distance inland.

I2.5 Coastal Storms

The NSW coastline is subject to intense tropical and non-tropical storms at irregular intervals. Key coastal storms that have affected the study area occurred in 1920, March and May 1925, May 1944, June 1945, September 1967, May-June 1974, August 1998 and June-July 2007. The most significant

[7] Wave height derived as discussed in Section I2.2.
[8] It is emphasised that wave setup only generally occurs at shorelines landward of typical surf zone wave breaking processes. It does not necessarily propagate upstream into estuary entrances.

of these in terms of damage along the coast were the 1974 storms. The May 1974 storm was particularly severe as it was accompanied by the highest water level ever recorded along the NSW coast.

So-called Category X storms (with H_s greater than or equal to 6m) have occurred on average every 2 years offshore of Sydney from 1880 to 2007 (WorleyParsons, 2009). However, the time period between storms has not been uniform. For example, there were no Category X storms from 1880-1891, 1900-1907, 1946-1951, 1960-1965, 1969-1973 and 1979-1982. Also, there were 3 Category X storms in 2007, and two in each of the years of 1926, 1937, 1954, 1957, 1958, 1959, 1978, 1990, 1999, 2001, 2005 and 2006.

Damaging storms in the study area have generally occurred as a closely linked series of storms, rather than being particularly severe storms in isolation. In this way the beach may already be in a depleted state at the time of arrival of the second and subsequent storms. A key factor in the erosiveness of a storm, besides the storm energy, is also the water level occurring during the storm.

The study area has been subject to damaging coastal storms in the past, and can thus be expected to again be exposed to such storms at irregular intervals in the future. These storms are most likely to occur in Autumn and Winter, and are least likely to occur in Summer, but can generally occur at any time[9].

I2.6 Coastline Evolution

It should be recognised that Warringah's coastline is a dynamic environment that not only erodes and accretes in response to short term storm activity and calmer beach building conditions, but dramatically changes over geological time scales.

PWD (1985) noted that about 120,000 years ago, mean sea level was about 1m to 2m higher than at present. World temperatures then became progressively colder, with mean sea level lowering to around 140m below its present position about 17,000 years ago. At that time, Warringah's coastline was located about 20km offshore from its present position.

As warmer conditions then prevailed, sea level gradually rose to near its present level about 6,000 years ago. A new sandy coastline and dune system thus formed as sand moved onshore under the action of waves and currents as the sea level rose. Narrabeen Lagoon was formed as the beach system developed and cut off existing creek valleys (PWD, 1985).

I2.7 Sediment Transport

I2.7.1 Preamble

In the region between where waves break and the shoreline, two natural forms of sediment transport occur, namely longshore sediment movement (Section I2.7.2) and onshore/offshore sediment movement (Section I2.7.3). Sediment transport can also occur due to the action of wind

[9] Based on analysis of wave data collected offshore of Sydney, it is evident that the Autumn and Winter seasons have been the most stormy (based on relative wave energy), with June, July and May (in descending order of storminess) having been the most stormy months. The Winter period has been greater than three times more stormy than Summer, with January and February being the least stormy months. Autumn and Winter combined has been more than twice as stormy as Spring and Summer combined.

(Section I2.7.4). Lagoon entrances (and to a lesser extent stormwater systems) may also contribute sediment to or capture sediment from the beach system (Section I2.7.5). Manual forms of sediment transport, namely beach nourishment, beach sediment recycling and beach scraping, are discussed in Section I2.7.6.

Long term measurements of beach volume changes in the study area are described in Section I2.7.7. The overall sediment budget for these beaches is discussed in Section I2.7.8. The long term recession rates due to net sediment loss adopted for these beaches are listed in Section I2.7.9.

I2.7.2 Longshore Sediment Transport

Longshore sediment transport is associated with longshore currents. Longshore currents occur between where waves break and the shoreline, and are generated by (NSW Government, 1990):

- waves breaking at an angle to the shoreline;
- feeder currents to rip cells; and,
- longshore variations in water level resulting from nearshore wave conditions and wind stress.

Longshore currents essentially move parallel to the shoreline. These currents cause movement of sediment along the shoreline, commonly referred to as littoral drift. Due to the variability in wave approach direction at beaches (and other wind and wave conditions), there may be times when the littoral drift is in one direction and at other times when it is in the opposite direction.

The beaches in the study area are generally surrounded by headlands (Narrabeen Head and Long Reef) that would be expected to limit the transfer of sediment between embayments. That is, the Collaroy-Narrabeen Beach and Fishermans Beach embayment can generally be considered to be a closed compartment with regard to longshore sediment transport, in that it does not supply significant volumes of sediment to adjacent embayments nor gets supplied with significant volumes of sediment from adjacent embayments (PWD, 1985)[10]. There are also other indicators of the Collaroy-Narrabeen Beach and Fishermans Beach embayment being a closed compartment, such as negligible change in beach volume over time (see Section I2.7.7).

I2.7.3 Onshore/Offshore Sediment Transport

Onshore/offshore (also known as cross-shore) sand movement is caused by natural variations in wave climate and water level. The offshore movement of sand is usually referred to as storm erosion. This onshore/offshore movement of sand results in short term fluctuations in the volume and width of the beach profile.

During storms with relatively large and steep waves, beach sand moves offshore to form bars. This process typically occurs over a period of hours to days. When extended periods of calmer wave conditions occur (characterised by relatively long period and low height swell, that is less steep waves), the material held in these bars migrates onshore to rebuild the beach. Depending on the magnitude of the preceding storm, this beach building process can occur over a time scale of days to years.

[10] It is recognised that there may be some transport of sand around Narrabeen Head to Turimetta Beach, so the entire closed compartment may also include Turimetta Beach. That stated, this transport is generally insignificant with regard to the conclusions drawn herein.

The amount of sand which can be removed from a beach during a storm event (or series of closely spaced storms) and transported offshore is referred to as the “storm demand”. This quantity is generally measured above 0m AHD (approximately mean sea level), and is usually expressed as a volume per metre length of beach (m^3/m). Knowledge of the storm demand for a beach allows estimation of the amount of material required to be held in reserve for a storm in order to protect a given asset landward of the beach. It also allows estimation of the degree to which a beach would be eroded or cut back in a storm for a given pre-storm beach profile.

I2.7.4 Aeolian (Windblown) Sediment Transport

Aeolian sand transport can occur at beaches when (usually) dry sand is entrained by aeolian (wind) processes, particularly if the dunes are not densely covered by vegetation or protected by a seawall. In the past (before the late 1970’s), aeolian sediment transport issues were more significant in Warringah than at present due to the lack of dune vegetation coverage in these earlier times, particularly at areas such as north of Devitt Street at Narrabeen. That stated, there are examples of windblown sand issues occurring in recent years, see Figure I1, Figure I2 and Figure I3[11].

The importance of sand stabilisation provided by dune vegetation cannot be understated. Dune vegetation is necessary to stabilise dune systems and protect them from wind erosion into the future.

Figure I1: Windblown sand at properties north of Mactier Street, 10 June 2007

[11] Wave uprush may have also contributed to some of the sand transport in all of these examples.

Figure I2: Windblown sand at Clarke Street, 10 June 2007

Figure I3: Windblown sand at Stuart Street, 10 June 2007

I2.7.5 Sand Transport at Lagoon Entrances

Narrabeen Lagoon is a temporary sink for sediment, with sand naturally building up in the entrance over time between manual entrance clearance operations. These entrance clearance operations are typically undertaken every 3 to 4 years, with around 40,000m^3 to 45,000m^3 of sediment removed in each of three recent clearance operations in 1999, June-September 2002 and October-December 2006 (Cameron et al, 2007)[12], and 36,000m^3 removed in the last operation from September to November 2011[13].

[12] Further information on the 2002 and 2006 entrance clearance campaigns is provided in Patterson Britton & Partners (2002, 2003) and Cardno Lawson Treloar (2008).
[13] Daylan Cameron (formerly Warringah Council), personal communication.

After removal from the entrance, the sediment has been transported by trucks and placed and spread on Collaroy-Narrabeen Beach. In the 2006 works, sand was placed at the following locations (Cameron et al, 2007):

- between about the high water mark and the fence line of properties near the ends of Mactier, Clarke, Wetherill, Stuart and Frazer Streets; and,
- between about the high water mark and the vegetation line of the dunes adjacent to the car park north of the Collaroy Services Beach Club.

In 2011, sand was placed on Collaroy-Narrabeen Beach between Jenkins Street and Mactier Street, spread between the shoreline and property boundaries to ensure a uniform terrain. Four access points were used in this work, namely (from north to south) Mactier Street, Wetherill Street, Stuart Street and the Collaroy Beach Car Park opposite Jenkins Street[13].

There was also about 25,000m^3 of sediment removed from the Narrabeen Lagoon entrance in 1990, 35,000m^3 removed in 1992-1993 and 17,000m^3 removed in 1995 (Patterson Britton & Partners, 2003), and a total of 29,000m^3 removed in discrete campaigns in 1979, 1982, 1983 and 1987 (Gordon, 1989). A larger removal of 100,000m^3 occurred in 1975, from which the Birdwood Park dune was constructed.

It would be expected that every 3 to 4 years, manual entrance clearance operations would continue as they have in the past (or an alternative entrance clearance system would be adopted), and thus there would be no significant net loss of sediment from the Collaroy-Narrabeen Beach sediment budget system caused by Narrabeen Lagoon entrance infilling.

Narrabeen Lagoon is a managed entrance, in that it is opened mechanically when water levels reach a specified level. This is mainly undertaken for flood mitigation purposes, but also has benefits for water quality and recreation.

At the various stormwater systems that discharge on to beaches in the study area, depressions typically occur in the beach profile during significant rainfall events, which can remain for some time after the event. Various examples of these depressions are provided in **Appendix G** (such as Figure G1, G3, G9, G10, G12, G13 and G23). The temporary loss of sand from the subaerial portion of beaches at stormwater outlets during rainfall-runoff is unlikely to be significant in terms of the overall sediment budget of the beaches. However, the presence of any stormwater-induced scouring may exacerbate the landward extent of coastal erosion in the vicinity of stormwater outlets. The stormwater systems would not be expected to supply any significant quantities of sand to the beach system.

I2.7.6 Beach Nourishment, Beach Sediment Recycling and Beach Scraping

<u>Beach Nourishment</u>

Beach nourishment involves adding sand to a beach, with the sand obtained from another location (from outside the sediment budget system for the beach). Beach nourishment can be used to maintain and enhance the recreational amenity of a beach, provide some additional protection for beachfront development at threat, and to improve public safety.

In Warringah LGA, beach nourishment is typically undertaken when sand excavated from building sites is deposited on beaches in the LGA (particularly at Collaroy-Narrabeen Beach).

Since December 2001, Council has placed about 50,300 tonnes (30,500m^3) of sand on Collaroy-Narrabeen Beach, derived from building development excavations (such as for basement car parking) in Narrabeen, Collaroy and Manly. Supply of this sand can be made a condition of consent placed on proponents when Council approves Development Applications.

The sand has been typically transported to the beach using bogie tipper trucks (6 wheel and 12 tonne), see left image in Figure I4, and placed on the beach reserve between Jenkins Street at Collaroy and Devitt Street at Narrabeen (with Wetherill Street and Mactier Street at Narrabeen being the two main access points). The deposited sand has been spread using excavators, loaders, backhoes and bulldozers (see right image in Figure I4).

Figure I4: Bogie tipper truck depositing sand (left), and being spread by machinery (right) at Collaroy-Narrabeen Beach

It is recommended that the practice of sourcing sand from building sites (and other sources) continues, if testing and visual inspection indicates that the sand source is suitable for use (eg suitable grain size, colour, and free of debris and contaminants).

Aecom (2010) completed a scoping study investigating the feasibility of undertaking beach nourishment in Sydney (with a particular focus on Collaroy-Narrabeen Beach as one of three beaches investigated in more detail), using offshore sand sources. At present, extraction of sand from offshore of NSW is not permitted. Beach nourishment can also be undertaken using sand from terrestrial and estuarine/river sand supply sources.

Beach Sediment Recycling

Using the terminology defined in CIRIA (2010), the regular Narrabeen Lagoon entrance clearance operations with placement of sand on Collaroy-Narrabeen Beach can be denoted as "beach sediment recycling" (the mechanical movement of beach sediment from downdrift to updrift)[14]. These lagoon sand extraction activities are different to beach nourishment as the operations only redistribute sediment within the Collaroy-Narrabeen Beach sediment budget system, as opposed to being an external source adding to the sediment store in the system.

[14] This was formerly described by Council as "beach replenishment", but as this term is synonymous with beach nourishment (CIRIA, 2010) it has not been adopted herein. "Beach sediment recycling" involves redistributing sand within a particular embayment.

Beach Scraping

Another form of mechanical sand redistribution on beaches is beach scraping. Beach scraping is defined as the movement of relatively small to medium quantities of sand from the lower part of the beach profile in order to assist in rebuilding the dune system and upper beach profile, by mechanical means (typically using earthmoving equipment such as bulldozers). Beach scraping has been undertaken by Council in the past at Dee Why Beach and Collaroy-Narrabeen Beach to accelerate beach recovery after storm events and to bury exposed areas of protective works that may present a public safety risk. An example of a beach scraping operation at Dee Why Beach is shown in Figure I5.

Figure I5: Beach scraping operation at Dee Why Beach in September 2007

I2.7.7 Long Term Measurements of Beach Changes

Measurement of long term historical variation in beach volume and beach position at Collaroy-Narrabeen Beach and Fishermans Beach is useful in the consideration of the likelihood of any future long term recession at these beaches due to net sediment loss.

Analysis of photogrammetric data for 13 dates collected from 1941 to 2006 at Collaroy-Narrabeen Beach and Fishermans Beach has been undertaken (WorleyParsons, 2009). To summarise:

- It was observed that Collaroy-Narrabeen Beach has been relatively stable over the period of photogrammetric record, with accretion (progradation) generally evident (for example, in the order of 0.1m/year for the 1951-2006 and 1961-2006 periods, the longest periods covering the entire beach). The only area with evidence of long term recession (considering dates pre-1974) was in the vicinity of Fielding Street to Wetherill Street, but this area has shown accretion for all analysis periods commencing since that time.

- Slight historical recession has occurred at Fishermans Beach based on the data analysed, in the order of -0.05m/year for the 1941-2006 and 1951-2006 periods.

Approximately monthly measurements of beach volume have been undertaken at 5 cross-shore profiles[15] along Collaroy-Narrabeen Beach since April 1976 (WorleyParsons, 2009). The variation in beach volume and width with time from this data set is depicted in Figure I6 and Figure I7 respectively. Statistically, trends were as follows for the 1976 to 2008 period:

- accretion of beach volume averaged over the entire beach of 0.5m^3/m/year (Figure I6);
- recession of the 0m AHD shoreline position averaged over the entire beach of -0.03m/year (Figure I7); and
- tendency for the northern two profiles to accrete more than average, and Profiles 4 and 8 to recede more than average (with Profile 6 relatively stable), over a period where El Niño conditions have dominated on average (mean Southern Oscillation Index of -2.7 over the analysis period[16]).

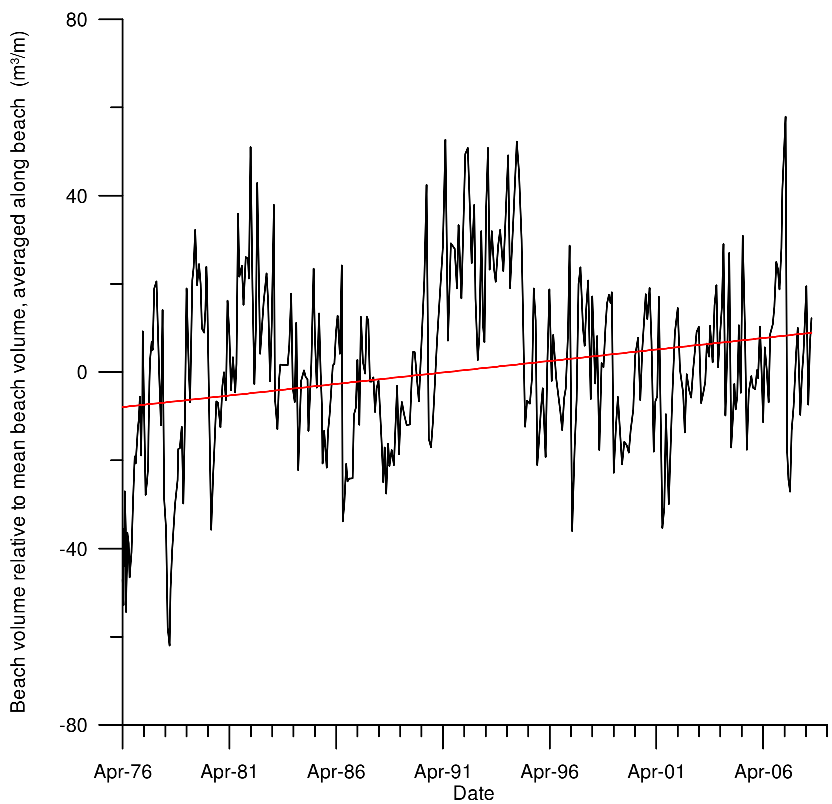

Figure I6: Variation in overall beach volume (relative to mean) along Collaroy-Narrabeen Beach from 1976 to 2008, with linear trendline shown

[15] The 5 profiles were denoted moving from north to south as Profiles 1, 2, 4, 6 and 8 (located at Malcolm, Octavia, Narrabeen, Wetherill and Collaroy Streets respectively).
[16] As discussed in Section I2.8.2 and I3.4, El Niño conditions (negative Southern Oscillation Index) would be expected to favour Collaroy-Narrabeen Beach rotating clockwise (with the northern end accreting and southern end receding).

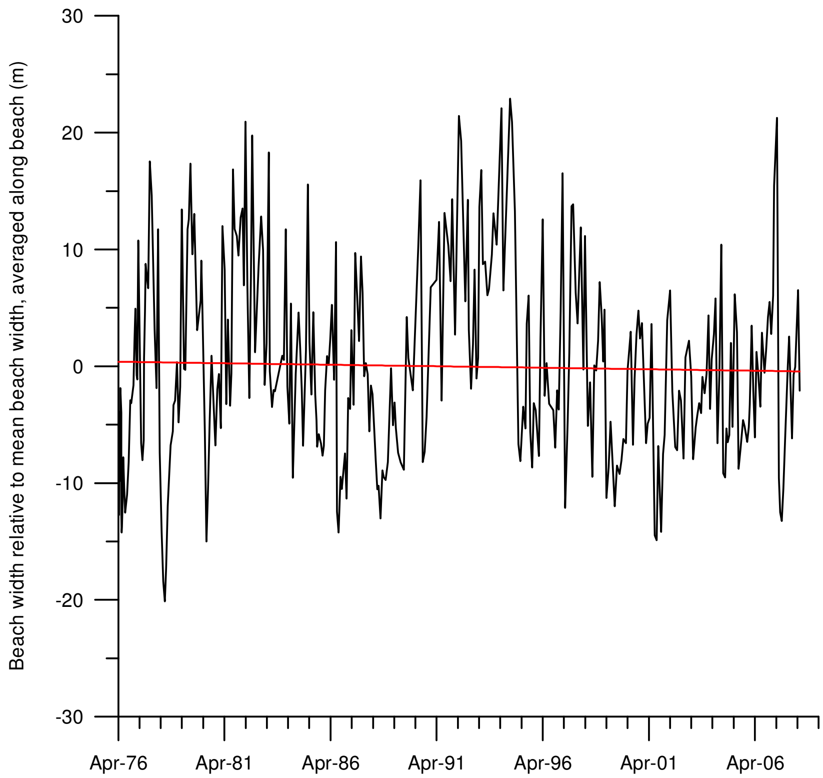

Figure I7: Variation in beach width (relative to mean) averaged along entire Collaroy-Narrabeen Beach from 1976 to 2008, with linear trendline shown

I2.7.8 Overall Sediment Budget

The relative long term stability of Collaroy-Narrabeen Beach and Fishermans Beach as measured over the last 60 or so years provided evidence that the overall sediment budget for the Collaroy-Narrabeen Beach and Fishermans Beach embayment is likely to be essentially closed. That is, there are likely to be no significant net gains or losses of sand into or from this embayment. This is because there is likely to be no significant transport of sand over the four boundaries of the beach system, namely the:

- northern and southern (headland) boundaries: as noted in Section I2.7.2, there is little longshore transport over these boundaries due to the presence of rocky headlands and reefs;
- seaward boundary: sand transported offshore in storms would be expected to generally return in calmer conditions, such that there would be no net loss from the sediment budget system (as noted in Section I2.7.3); and,
- landward boundary: due to general dunal vegetation coverage and seawalls there is little opportunity for sand to be lost or gained from/to the beach system in a landward/seaward direction (as noted in Section I2.7.4), and although Narrabeen Lagoon may be a temporary or potential sediment sink, sand is periodically removed from the entrance and placed back on Collaroy-Narrabeen Beach such that there is no longer term net loss from the sediment budget system (as noted in Section I2.7.5)[17].

[17] Stormwater systems also do not supply or remove any significant quantities of sand to/from the sediment budget system (see Section I2.7.5).

Beach nourishment is a potential source of sand for the study area, with 30,500m^3 of sand added from building sites to Collaroy-Narrabeen Beach over about the last 10 years (Section I2.7.6). Beach sediment recycling and beach scraping (also discussed in Section I2.7.6) only redistribute sand within beach embayments, and hence neither provide sediment budget "sinks" nor "sources" (that is, neither add sand to or remove sand from the beach system).

Sediment budget "sinks" in the study area in the past have included removal of sand by human activities. These activities have included dune sand extraction for construction purposes (for example, north of North Narrabeen SLSC), and extraction of sand from the Narrabeen Lagoon entrance channel nourishment of other beaches[18]. These activities are not appropriate practices and would not be expected to occur again in the study area.

I2.7.9 Adopted Long Term Recession Rates Due to Net Sediment Loss

Based on review of the photogrammetric data and monthly beach volume data as described in Section I2.7.7, long term recession rates due to net sediment loss of 0.05m/year were adopted for both Collaroy-Narrabeen Beach and Fishermans Beach.

I2.7.10 Brief Discussion on Birdwood Park Dune

The North Narrabeen (Birdwood Park) dune north of North Narrabeen SLSC was artificially created in 1975, using about 100,000m^3 of sand removed from the Narrabeen Lagoon entrance (Section I2.7.5). Before that time, the present dune area was unvegetated (see Figure I8) and was relatively low.

In major coastal storms in 1974, the low dune was overtopped by waves. Wave action then damaged the area in the vicinity of the Ocean Street bridge. Rocks were also washed up to 40m into the caravan park adjacent to Narrabeen Lagoon. The dune was built, and needs to be maintained, at a sufficient volume and elevation to reduce the risk of this happening again.

The North Narrabeen dune has grown naturally since its creation in 1975, mainly through trapping of windblown sand moving onshore (see **Appendix D1.1.2**) . Some have stated that the buildup of the North Narrabeen dune has removed sand feeding offshore sand banks, and thus detracted from surfing quality at North Narrabeen. It is considered to be more likely that (often windblown) sand naturally captured in this dune is sand that would have otherwise ended up in the Lagoon if the dune was not present. Indeed, without the dune it is expected that there would be faster transport of sand into the Lagoon and relatively less sand in the beach and surf zone area, compared to current conditions.

The amount of sand offshore is largely dependent on storm action (beach erosion). Offshore sand volumes may have reduced since 1974, affecting surf quality, due to the relative lack of storms since that time.

That is, although the Birdwood Park dune has grown over the last few decades, it is considered that this has generally been capturing sand that would have otherwise moved into Narrabeen Lagoon, as opposed to taking sand away from surf breaks.

[18] For example, sand has been removed from the entrance as follows: 12,000m^3 in both 1979 and 1981 to Freshwater Beach; 5,000m^3 in 1979 to Long Reef Beach; and 6,000m^3 in 1982 to Warriewood Beach (Gordon, 1989).

Figure I8: Present Birdwood Park area in 1943, with current vegetation line and North Narrabeen SLSC positions shown

I2.8 Climate Change

I2.8.1 Sea Level Rise

The possibility of global climate change accelerated by increasing concentrations of greenhouse gases, the so-called Greenhouse Effect, is widely accepted by the scientific and engineering communities. This is predicted to cause globally averaged surface air temperatures and sea levels to rise.

The latest (Fifth Assessment) Intergovernmental Panel on Climate Change (IPCC) estimates of future sea level rise were released in 2013 (IPCC, 2013a, b). The global mean sea level rises projected by IPCC (2013a) to 2100 are shown in Figure I9. The different colours represent different representative concentration pathways (RCP), where these scenarios represent a range of 21st century climate policies with regard to changes in greenhouse gas emissions. The assessed likely range is shown as a shaded band. The assessed likely ranges for the mean over the period 2081–2100 for all RCP scenarios are given as coloured vertical bars, with the corresponding median value given as a horizontal line.

For example, for the most severe RCP8.5, global mean sea level rise for 2081-2100 relative to 1986-2005 will likely be in the range of 0.45 to 0.98m.

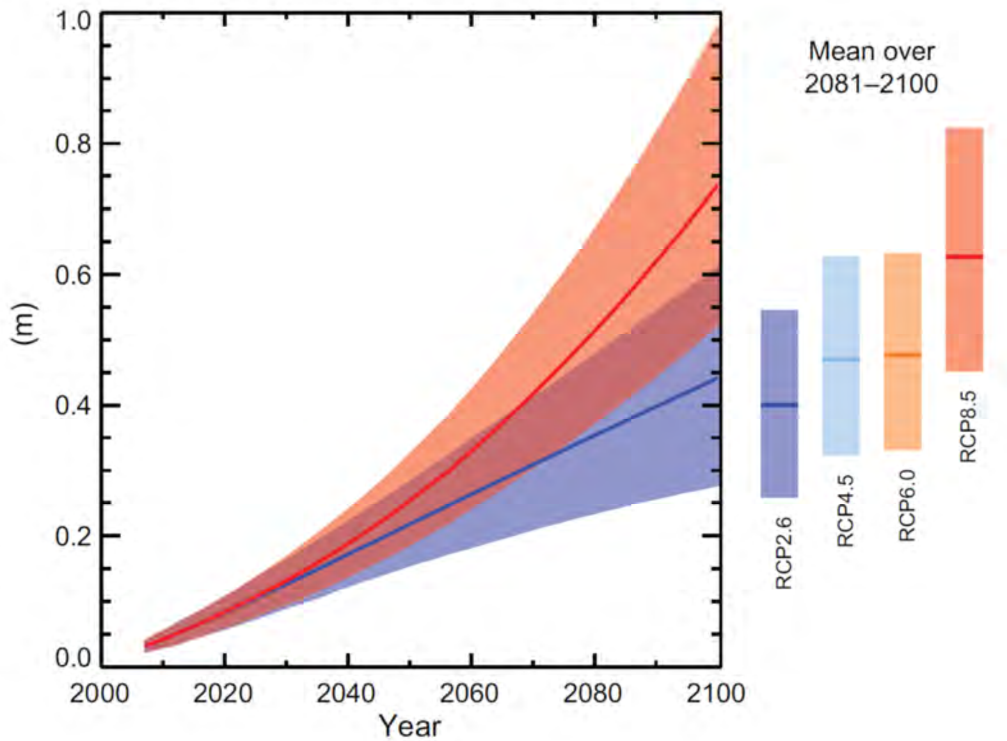

Figure I9: Global mean sea level rise predicted to 2100 relative to 1986-2005 based on various representative concentration pathways (IPCC, 2013a)

It should be emphasised that future sea level rise could be smaller or larger than projected. The actual sea level rise that would occur is uncertain due to approximations in the modelling used to develop the projections, plus the fact that the results are dependent on the emission scenario (RCP) adopted (which would vary depending on a variety of economic and political influences, with no specific probability assigned to any particular scenario). However, note that global average temperature and sea level are projected to rise under all RCP.

The *NSW Sea Level Rise Policy Statement* (DECCW, 2009b) was released in October 2009[19]. It included sea level rise planning benchmarks of 0.4m at 2050 and 0.9m at 2100 (both relative to 1990), with the two benchmarks allowing for consideration of sea level rise over different timeframes. The sea level rise planning benchmarks can be used for purposes such as incorporating the projected impacts of sea level rise on predicted flood risks and coastline hazards. However, note that DECCW (2009b) is no longer NSW government policy (see **Appendix H**) .

[19] Note that this was based on the previous (fourth) IPCC assessment as per IPCC (2007) and Meehl et al (2007).

For the Appendix herein, the DECCW (2009b) values were adopted as advised by Council. It can be noted, as stated in DECCW (2009b), that "the benchmarks are not intended to be used to preclude development of land that is projected to be affected by sea level rise. The goal is to ensure that such development recognises and can appropriately accommodate the projected impacts of sea level rise on coastal hazards and flooding over time, through appropriate site planning, design and development control".

As discussed in Section I3.5.3, it is generally expected that recession of the open coast will occur under conditions of accelerated sea level rise.

I2.8.2 Other Climatic Change Considerations

Another potential outcome of climate change is an increase in the frequency and intensity of storm events.

Modest to moderate increases in average and maximum cyclone intensities are expected in the Australian region in a warmer world. However, cyclone frequency and intensity are strongly associated with the El Niño/Southern Oscillation (ENSO) phenomenon. How this phenomenon will vary in a warmer world is currently unknown (CSIRO, 2001; CSIRO Marine Research, 2001).

Mid latitude storms have been predicted to increase in intensity but decrease in frequency with global warming (CSIRO, 2002), due to a reduction in equator to pole temperature gradients. However as with tropical cyclones, climate modelling at present lacks the resolution to accurately predict changes associated with global warming.

If overall weather patterns change as a result of global warming, there is potential for changes in the angle of approach of the predominant wave climate (Moratti and Lord, 2000). For some beaches this may cause realignment of the shoreline, with resulting recession and accretion.

Based on studies of Palm Beach and Collaroy-Narrabeen Beach in Sydney, there have been attempts (Ranasinghe et al, 2004) to explain beach realignment/rotation in terms of shifts in the Southern Oscillation Index (SOI)[20]. Specifically, Ranasinghe et al (2004) proposed that beaches rotate clockwise (with the northern end accreting and southern end receding) in El Niño phases (negative SOI). Conversely, it was proposed that beaches rotate anti-clockwise (with the northern end receding and southern end accreting) in La Niña phases (positive SOI)[21]. In both cases, the beach response at the northern end lagged SOI trend shifts by about 3 months, while the beach response at the southern end lagged SOI trend shifts by about 17 months.

It has been postulated that, as a result of the greenhouse effect, El Niño conditions will be favoured in the future (Cai and Whetton, 2000; Boer et al, 2004), thus favouring clockwise beach rotation. In the study area, this would most likely have a negative effect on the southern end of beaches.

Given the above uncertainty and difficulty in quantitative prediction, no specific account was taken of any potential changes to storm frequency and intensity, or changes in wave directions, in the

[20] The SOI is calculated from the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin. The method used by the Australian Bureau of Meteorology is the Troup SOI which is the standardised anomaly of the Mean Sea Level Pressure difference between Tahiti and Darwin (Bureau of Meteorology, 2005).
[21] It was also found that La Niña phases were associated with more energetic (erosive) conditions.

Appendix herein[22]. However, this uncertainty should be taken into consideration when assessing the risk and consequences of recession occurring in the future. The potential for climate change related recession needs to be continually reviewed as more information develops in the scientific community.

[22] A generally conservative approach was used in the estimation of other coastline hazards, in particular storm demand, in the Appendix herein. A probabilistic approach to hazard definition, including further consideration of other climatic change considerations, is provided in **Appendix L**.

I3. COASTLINE HAZARDS

I3.1 Preamble

Potential coastline hazards that could impact on the study area are defined in subsequent sections, namely:

- beach erosion (Section I3.2), with discussion on the selection of suitable base profiles for hazard definition in Section I3.3;
- beach rotation (Section I3.4);
- shoreline recession (Section I3.5);
- stormwater erosion (Section I3.6);
- slope instability (Section I3.7); and
- coastal inundation (Section I3.8).

The Immediate, 2050 and 2100 Hazard Lines for Collaroy-Narrabeen Beach and Fishermans Beach are depicted in Section I3.9.

In defining these coastline hazards, an entirely sandy subsurface was assumed. That is, existing protective works that are presently effective (to varying degrees) in limiting storm demand in the study area were ignored for calculation purposes. Similarly, areas with natural bedrock or other inerodible subsurface materials (such as stiff clays) in the area of active erosional coastal processes were not accounted for in the analysis.

Assuming an entirely sandy subsurface was considered to be appropriate for presentation purposes as:

- it is not possible to predict storm demand on beaches with protective works in place, when these works have uncertain effectiveness;
- it is a useful planning tool to predict coastline hazards with no protective works in place, as these may not be maintained and may fail into the future;
- a detailed understanding of subsurface conditions would be required to account for inerodible subsurface materials (such as stiff clays), and there is not widespread availability of this information in the study area;
- areas with likely protective works and inerodible subsurfaces have been identified in the figures depicting the hazard lines;
- it was how previous coastline hazard assessments for the study area have been undertaken;
- it was agreed to take this approach in consultation with Council and OEH;
- it is conservative to do so; and,
- the presence of protective works and inerodible subsurfaces was accounted for in the subsequent risk assessment in **Appendix L**.

I3.2 Beach Erosion (Storm Demand)

During storms, large waves, elevated water levels and strong winds can cause severe erosion to sandy beaches. The hazard of beach erosion relates to the limit of erosion that could be expected due to a severe storm or from a series of closely spaced storms (NSW Government, 1990).

The beach erosion hazard is analogous to the "storm demand" discussed in Section I2.7.3. There are at least five methods available to estimate storm demand in the study area, namely:

- analysing measurements of beach erosion that have been collected at Collaroy-Narrabeen Beach;
- comparing measurements of beach erosion that have been collected at other similar beaches;
- storm cut numerical modelling;
- recently developed statistical joint probability type distribution approaches; and,
- correlating storm demand to relative wave energy exposure along the beaches in the study area.

As described by WorleyParsons (2009), it is evident that these various methodologies to estimate storm demand produce relatively consistent results of about 200m^3/m to 250m^3/m for the 100 year average recurrence interval (ARI) storm demand (above 0m AHD) at the most exposed areas of Collaroy-Narrabeen Beach[23]. In summary:

- approximate direct measurements of storm demand at Collaroy-Narrabeen Beach have been up to about 240m^3/m;
- a 100 year ARI storm demand of 220m^3/m was reported by Gordon (1987) for exposed NSW beaches at rip heads;
- simulation of three consecutive 100 year ARI storms in the storm cut numerical model SBEACH gave modelled storm demand values at Narrabeen Beach of about 180 m^3/m to 240m^3/m, as considered by Carley and Cox (2003); and
- the work of Callaghan et al (2008, 2009) indicated that 100 year ARI storm demand values at Collaroy-Narrabeen Beach were about 220m^3/m to 250m^3/m.

On this basis, it is considered to be reasonable to adopt a 100 year ARI storm demand above 0m AHD of 250m^3/m for fully exposed sections of the study area. This value was thus adopted for all beaches except the more protected southern end of Collaroy Beach, and Fishermans Beach.

In the less exposed areas (southern end of Collaroy Beach, and Fishermans Beach), a reduction in storm demand is considered to be reasonable on the basis of relative wave energy. Based on WorleyParsons (2009), the following storm demand values above 0m AHD (which are likely to be conservative) were adopted at Collaroy-Narrabeen Beach:

- 250m^3/m north of Frazer Street;
- linearly reducing to 200m^3/m at Collaroy Services Beach Club; and
- linearly reducing to 150m^3/m south of Collaroy SLSC.

At Fishermans Beach, a storm demand value of 100m^3/m was adopted.

[23] Note that it is difficult to assign a probability to the storm demand, being dependent on numerous factors such as wave height, water level, rip formation, antecedent beach volume, etc. However, a 100 year ARI is likely to be a minimum ARI to assign to erosion volumes of 250m^3/m. That is, such events causing beach erosion of this magnitude may be in the order of 200 year ARI or higher. It is considered to be reasonable to adopt a conservative storm demand value given the uncertainties involved and immediate nature of the hazard.

I3.3 Base Profiles for Hazard Definition

To determine the position of the Immediate Coastline Hazard Line, photogrammetric profiles were used to define the pre-storm beach profile shape. To define the Immediate Hazard Line, a storm demand volume was applied to each photogrammetric beach profile to estimate the landward storm cut distance into the dune.

It is most appropriate to select a relatively accreted profile as the base (pre-storm) profile for hazard definition, typically known as an “average beach-full” profile in NSW coastal engineering practice, as storm demands in the order of 250m^3/m can only occur at accreted beaches. This is because eroded beaches have lower storm demands due to dissipation of wave energy on offshore bars formed by antecedent storms (Harley et al, 2009). It is also advantageous to select a relatively recent profile, where possible, such that the base profile is relatively similar to the current general shape of the beach[24].

As discussed in WorleyParsons (2009), year 2006 base profiles were adopted for hazard definition at Collaroy-Narrabeen Beach and Fishermans Beach.

I3.4 Beach Rotation

As noted in Section I2.8.2, there is evidence that Collaroy-Narrabeen Beach rotates in response to shifts in the Southern Oscillation Index. As described by WorleyParsons (2009), beach rotation at Collaroy-Narrabeen Beach was accounted for by adjusting the 2006 base profiles (see Section I3.3), which were relatively eroded at the north end of Collaroy-Narrabeen Beach, and relatively accreted at the south end. An “average beach full” shoreline (0m AHD) position was determined as the midpoint between the mean and maximum (most accreted) shorelines based on measurements approximately once per month from 1976 to 2008. The difference in position of the 2006 shoreline to the average beach full shoreline was then determined. The adjustment applied for hazard definition was 50% of this difference[25].

No allowance for beach rotation at Fishermans Beach was included as per WorleyParsons (2009).

I3.5 Shoreline Recession Hazard

I3.5.1 Preamble

The hazard of shoreline recession is the progressive landward shift in the average long term position of the coastline (NSW Government, 1990). Two potential causes of shoreline recession are net sediment loss, and an increase in sea level, as outlined in Sections I3.5.2 and I3.5.3 respectively. It is also appropriate to discount (in the assessment of recession due to net sediment loss) any potential recession due to actual sea level rise that may have occurred over the measurement period of the photogrammetric data[26], as discussed in Section I3.5.4.

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[24] Selecting old profiles, or averaging numerous profiles, can create profile shapes that do not resemble the current beach. This is particularly the case where anthropogenic effects such as dune restoration works have dramatically altered beach profiles in the past.

[25] If the 2006 shoreline was seaward of the average beach full shoreline, the adjustment was landward. Conversely, if the 2006 shoreline was landward of the average beach full shoreline, the adjustment was seaward.

[26] The photogrammetric data measurement period was from 1941 to 2006 at Collaroy-Narrabeen Beach and Fishermans Beach (WorleyParsons, 2009).

I3.5.2 Long Term Recession Due to Net Sediment Loss

Long term recession due to net sediment loss is a long duration (period of decades), and continuing net loss of sand from the beach system. According to the sediment budget concept, this occurs when more sand is leaving than entering the beach compartment. This recession tends to occur when:

- the outgoing longshore transport from a beach compartment is greater than the incoming longshore transport;
- offshore transport processes move sand to offshore "sinks", such as gutters within reef systems, from which it does not return to the beach; and/or,
- there is a landward loss of sediment by windborne transport (NSW Government, 1990).

Shoreline recession due to net sediment loss should not be confused with beach erosion, with the latter resulting in a short term exchange of sand between the subaerial and subaqueous portions of the beach, not a net loss from the active beach system. Shoreline recession is therefore a long term process which is overlaid by short term fluctuations (erosion and accretion) due to storm activity.

The long term recession rate due to net sediment loss adopted in Section I2.7.9 was 0.05m/year at Collaroy-Narrabeen Beach and Fishermans Beach, which is equivalent to 2.2m at 2050 and 4.7m at 2100[27].

I3.5.3 Long Term Recession due to Sea Level Rise

A progressive rise in sea level may result in shoreline recession through two mechanisms: first, by drowning low lying coastal land, and second, by shoreline readjustment to the new coastal water levels. The second mechanism is probably the more important since a significant volume of sediment may move offshore as the beach seeks a new equilibrium profile (NSW Government, 1990).

Bruun (1962) proposed a methodology to estimate shoreline recession due to sea level rise, the so-called Bruun Rule. The Bruun Rule is based on the concept that sea level rise will lead to erosion of the upper shoreface, followed by re-establishment of the original equilibrium profile. This profile is re-established by shifting it landward. The concept is shown graphically in Bruun (1983), and can be described by the equation (Morang and Parson, 2002):

$$R = \frac{S \times B}{h + d_c} \tag{1}$$

where R is the recession (m), S is the long term sea level rise (m), h is the dune height above the initial mean sea level (m), d_c is the depth of closure[28] of the profile relative to the initial mean sea level (m), and B is the cross-shore width of the active beach profile, that is the cross-shore distance from the initial dune height to the depth of closure (m). This equation is a mathematical expression that the

[27] The rates are applied relative to 2006 base profiles, and from 2006 it is 44 years to 2050 and 94 years to 2100.
[28] The depth of closure is the water depth beyond which repetitive profile surveys (collected over several years) do not detect vertical sea bed changes, generally considered to be the seaward limit of littoral transport. The depth can be determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Note that this does not imply the lack of sediment motion beyond this depth (Szuwalski and Morang, 2001).

recession due to sea level rise is equal to the sea level rise multiplied by the average inverse slope of the active beach profile, with the variables as illustrated in Figure I10.

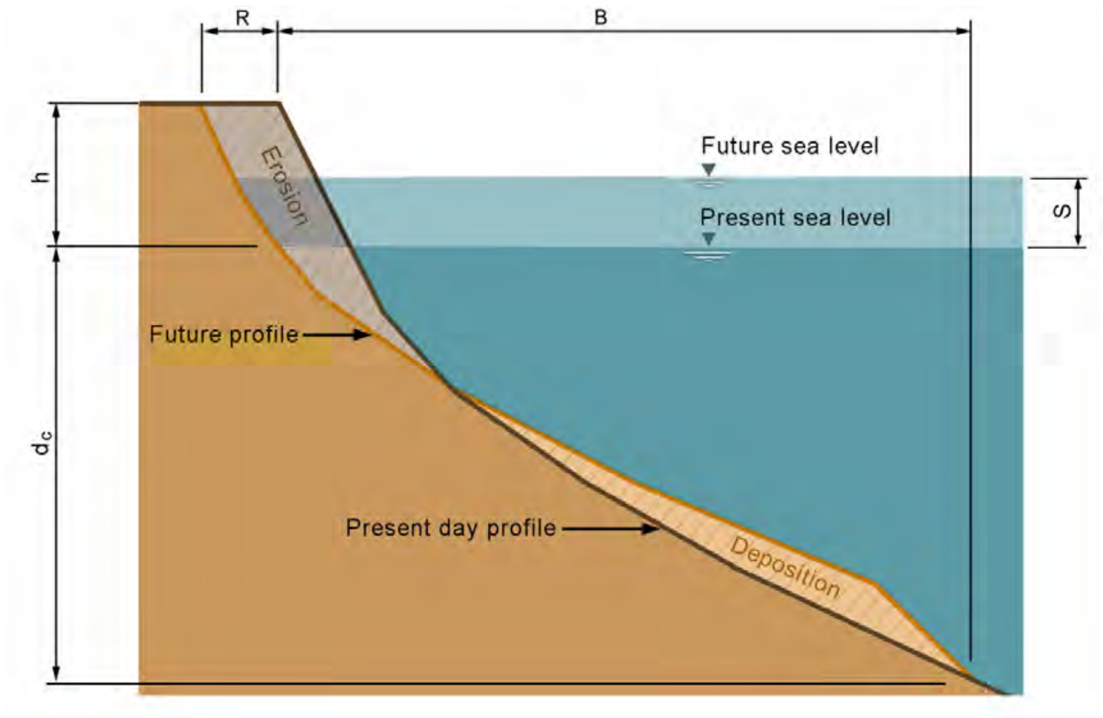

Figure I10: Illustration of variables in the Bruun Rule

The most difficult variable to estimate in the Bruun Rule is the depth of closure, and there are a number of methods to determine it as discussed in **Appendix J**. As noted in Appendix J, it is considered to be appropriate to adopt an "inner Hallermeier" closure depth, thus resulting in inverse slopes for use in the Bruun Rule as listed in Table I3.

Table I3: Adopted inverse slopes in Bruun Rule for beaches in study area

Beach	Inverse slope in Bruun Rule
Collaroy-Narrabeen	30
Fishermans	20

To apply these inverse slopes to estimate long term recession due to sea level rise, it is necessary to discount sea level rise that has occurred from 1990 to present. This is because the adopted 0.4m sea level rise at 2050 is defined to be relative to 1990 (see Section I2.8.1).

As described by DECCW (2010b), there was approximately 3mm/year of global sea level rise since 1990. For 2006 base profiles (16 years since 1990), there was thus 48mm of sea level rise to discount (that is, about 0.05m) Therefore, the actual sea level rise to apply at 2050 in using the Bruun Rule is 0.4 minus 0.05, that is 0.35m. Similarly, the sea level rise to apply at 2100 is 0.85m.

Therefore, for example, the projected long term recession due to sea level rise to 2050 at Collaroy-Narrabeen Beach is about 11m (30 multiplied by 0.35). The long term recession values due to sea level rise (relative to the 2006 base profiles) for each beach are summarised in Table I4.

Table I4: Adopted long term recession due to sea level rise values at 2050 and 2100

Beach	Long term recession (m) due to sea level rise at	
	2050	2100
Collaroy-Narrabeen	11	26
Fishermans	7	17

It should be noted that the Bruun Rule has been questioned in the scientific literature, for example by Cooper and Pilkey (2004), and also refer to Ranasinghe et al (2007). However, until alternative tools are available for practical application in the engineering community, it is considered to be reasonable to continue to use the Bruun Rule to estimate long term recession due to sea level rise as appropriate.

That stated, it should be recognised that there is uncertainty in the long term recession due to sea level rise estimates applied herein. Cowell et al (2006) developed a method of defining the uncertainty in the Bruun Rule predictions through describing its input variables with probability distributions. As an example of its application, Cowell et al (2006) estimated recession of 33.2m ± 90m (at the 90% confidence level) at Manly Ocean Beach at 2100, compared to the single estimate of about 25m of Patterson Britton & Partners (2008a). That is, it should be recognised that future recession could be seaward or landward of the predictions herein.

Ranasinghe et al (2012) has recently developed an alternative method to the Bruun Rule, based on a process based model of dune erosion and recovery to derive probabilistic estimates of sea level rise driven coastal recession. Application of this model is discussed in **Appendix L**.

I3.5.4 Consideration of Historical Recession Rates

Shoreline recession rates determined from historical data may be influenced by any sea level rise which occurred in the period of the historical record[26]. That is, although any long term recession that has occurred over the historical record would mainly be expected to have been caused by net sediment loss, given that there has also been some sea level rise over the historical record it can be argued that any historical long term recession has been partially caused by sea level rise.

Averaged around Australia, the relative sea level rise from 1920 to 2000 was about 1.2mm/year (CSIRO Marine Research, 2004), which is equivalent to a shoreline recession of about 0.04m/year (Collaroy-Narrabeen Beach) and 0.02m/year (Fishermans Beach). That is, the postulated recession due to historical sea level rise since the 1940's, which has occurred while the beaches in the study area have appeared to be relatively stable, is a further indication of the relative stability of these beaches.

Given the limitations in accuracy of the photogrammetric data, and the discrete date methodology (generally separated by numerous years) to assess changes over periods when anthropogenic effects have been significant, it is not considered warranted to adjust (reduce) the long term recession due to net sediment loss estimates noted in Section I3.5.2. It is conservative not to complete this adjustment.

I3.6 Stormwater Erosion Hazard

During major stormwater runoff events, stormwater that is collected from back beach areas and discharges into coastal waters can cause significant localised erosion to the beach berm. This in turn can allow larger waves to attack the beach and can cause migration of the stormwater discharge entrance if not structurally contained (NSW Government, 1990). Flow from stormwater pipes and outlets on beaches can also potentially scour the surrounding sand, creating erosion zones.

In the study area, although scour can occur around stormwater outlets, due account of this hazard has been made in the selection of the storm demand value. Within the limitation of the spacing of photogrammetric profiles for hazard definition, natural long-term lowering of beach berms surrounding stormwater outlets is explicitly accounted for in the volumetric analysis defining hazard line positions.

I3.7 Slope Instability

For sandy areas, based on Nielsen et al (1992), a number of coastline hazard zones can be delineated as shown in Figure I11.

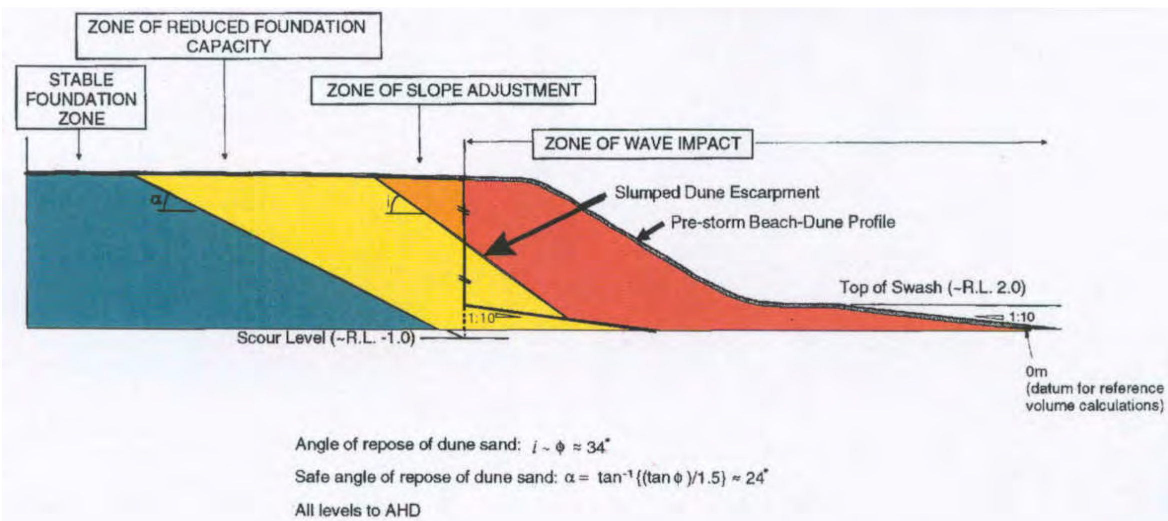

Figure I11: Schematic representation of coastline hazard zones (after Nielsen et al, 1992)

The *Zone of Wave Impact* delineates an area where any structure or its foundations would suffer direct wave attack during a severe coastal storm. It is that part of the beach which is seaward of the beach erosion escarpment[29] (as defined by the beach erosion hazard, see Section I3.2).

A *Zone of Slope Adjustment* (ZSA) is delineated to encompass that portion of the seaward face of the beach that would slump to the natural angle of repose of the beach sand following removal by wave erosion of the design storm demand. It represents the steepest stable beach profile under the conditions specified.

[29] The beach erosion escarpment is the steep (usually shore-normal) slope that is formed on a sandy beach when there is beach erosion, forming the link between the eroded and uneroded sections.

A *Zone of Reduced Foundation Capacity* (ZRFC) for building foundations is delineated to take account of the reduced bearing capacity of the sand adjacent to the storm erosion escarpment. Nielsen et al (1992) recommended that structural loads should only be transmitted to soil foundations outside of this zone (ie landward or below), as the factor of safety within the zone is less than 1.5 during extreme scour conditions at the face of the escarpment. In general (without the protection of a terminal structure such as a seawall), dwellings/structures not piled and located within the ZRFC would be considered to have an inadequate factor of safety.

Coastline hazard lines for the study area are determined in Section I3.9, corresponding to both the position of the landward edge of the ZSA and the landward edge of the ZRFC (defined at present, at 2050, and at 2100).

Geomarine (1991) found that typical ϕ values were 30° for loose sand, 35° for medium dense sand, and 38° for dense sand. A ϕ value of 35° was adopted for hazard line definition[30]. Scour levels of -1m AHD and 0m AHD were adopted by Geomarine (1991) at Collaroy-Narrabeen Beach and Fishermans Beach respectively, whereas a scour level of -1m AHD was adopted for both beaches herein as per WorleyParsons (2009).

I3.8 Coastal Inundation

Coastal inundation is the flooding of coastal lands by ocean waters, which is generally caused by large waves and elevated water levels associated with severe storms. Severe inundation is an infrequent event and is normally of short duration, but it can result in significant damage to both public and private property (NSW Government, 1990).

The components which give rise to elevated still water levels at times of storms have been referred to in Section I2.3, namely wind setup, barometric setup, and wave setup. Individual waves cause further temporary water level increases above the still water level due to the process of wave runup or uprush (Section I2.4).

In Section I2.4, 100 year ARI wave runup levels of 6m AHD (south of Fielding Street at Collaroy-Narrabeen Beach, and at Fishermans Beach) and 8m AHD (north of Fielding Street at Collaroy-Narrabeen Beach) were adopted. Taking sea level rise into account (Section I2.8.1), wave runup values may increase into the future, generally in the order of the magnitude of the sea level rise.

Wave runup levels of 6m to 8m AHD are above dune crest levels in parts of the study area, particularly:

- south of Devitt Street at Collaroy-Narrabeen Beach, and in particular south of Stuart Street, with the area surrounding Collaroy SLSC and Collaroy Services Beach Club being particularly vulnerable to coastal inundation as it is generally below 4m AHD; and
- at Fishermans Beach.

There is therefore the potential for occasional wave overtopping and coastal inundation in these areas. However, it should be noted that runup levels of 6m to 8m AHD would only be realised if the foreshore was at the runup height or higher. In reality, any waves that overtopped the foreshore in the study area would 'fold over' the foreshore crest and travel as a sheet flow at shallow depth, spreading out

[30] For six boreholes drilled at Collaroy-Narrabeen Beach, the sand in the active coastal zone was generally medium dense, dense or very dense.

and infiltrating over landward areas. A significant reduction in the velocity and depth of the runup would be expected within the order of 10m landward from the foreshore crest.

That is, even if a structure (in particular habitable floor level) was below a predicted wave runup level, this does not necessarily imply there would be damage to the structure, as this would depend primarily on the depth of overtopping flow (or flow momentum in immediate foreshore areas), and nature of the construction.

I3.9 Definition of Coastline Hazard Lines (Ignoring Protective Works and Inerodible Surfaces)

The Immediate, 2050 and 2100 coastline hazard lines for the study area are presented in Figure I12 to Figure I16 (hazard lines at landward edge of ZSA) and Figure I17 to Figure I21 (hazard lines at landward edge of ZRFC). In all cases an entirely sandy subsurface was assumed. That is, existing protective works and locations with inerodible subsurface materials in the area of active erosional coastal processes were not accounted for in the analysis.

The location of an asset landward of the Immediate Hazard Line does not mean it could not be affected by coastal erosion at present, rather that there is a low probability (in the order of 1% each year) of erosion extending landward of the Line at present. The location of known protective works is shown on the relevant Figures, but it is reiterated that future effectiveness of these works is uncertain (and cannot be guaranteed). Private lot boundaries are also shown in the Figures, and the aerial photography depicted on the Figures was captured on 29 January 2011.

Landward translations of the hazard lines due to long term recession were included after the storm demand was applied, and after adjustment to the 2006 profiles at Collaroy-Narrabeen Beach was made for beach rotation. This approach is simplistic as it assumes that the current dune morphology can essentially be translated landward over time. This issue is discussed further in **Appendix L** (Section L3.3.8).

To summarise the adopted hazard parameters:

- storm demand of 250m^3/m,
  - except at Collaroy Beach linearly reducing south of Frazer Street down to 200m^3/m at Collaroy Services Beach Club and then linearly varying down to 150m^3/m south of Collaroy SLSC; and,
  - except at Fishermans Beach adopting 100m^3/m;
- base profiles of 2006 for Collaroy-Narrabeen Beach and Fishermans Beach, including allowance for beach rotation at Collaroy-Narrabeen Beach only, adjusting 2006 profiles based on midpoint between the mean and maximum (most accreted) shorelines from 1976 to 2008;
- long term recession rate due to net sediment loss of 0.05m/year at both Collaroy-Narrabeen Beach and Fishermans Beach, giving 2.2m recession at 2050 and 4.7m recession at 2100;
- long term recession due to sea level rise at 2050 being about 11m at Collaroy-Narrabeen Beach and 7m at Fishermans Beach;
- long term recession due to sea level rise at 2100 being about 26m at Collaroy-Narrabeen Beach and 17m at Fishermans Beach; and
- calculation of hazard line positions at both the landward edge of the ZSA and the ZRFC respectively.

The hazard lines were determined over the full extent of photogrammetric data, with positions calculated at each photogrammetric profile location. The lines were not smoothed.

It is evident from the subsequent Figures that all existing development north of Devitt Street at Collaroy-Narrabeen Beach is landward of the Immediate ZSA. Most existing development north of Devitt Street is entirely landward of the 2050 ZSA, with four exceptions, namely at:

- 2 Loftus Street Narrabeen;
- 2 Wellington Street Narrabeen;
- 9 Albert Street Narrabeen; and
- 81 Ocean Street Narrabeen.

The area south of Devitt Street at Collaroy-Narrabeen Beach is a direct contrast to the area north. South of Devitt Street, about 80% of existing development has some portion seaward of the Immediate ZSA and 95% has some portion seaward of the 2050 ZSA (ignoring any existing protective works).

At Fishermans Beach, existing development at 9 Florence Avenue Collaroy, 3 Ocean Grove Collaroy, 1 Ocean Grove Collaroy and 11 Seaview Parade Collaroy has some portion seaward of the Immediate ZSA (ignoring any relatively inerodible subsurfaces). An additional 3 existing structures have some portion seaward of the 2050 ZSA, namely at 7 Florence Avenue Collaroy, 5 Seaview Parade Collaroy, and 1-3 Seaview Parade Collaroy (again ignoring any relatively inerodible subsurfaces).

At Collaroy-Narrabeen Beach, key public assets located at least partially seaward of the 2050 ZSA comprise various road heads and also South Narrabeen SLSC (ignoring any existing protective works). Collaroy SLSC and the car park north of Collaroy Services Beach Club have some portion seaward of the Immediate ZSA (again ignoring any existing protective works).

At Fishermans Beach, key public assets located at least partially seaward of the 2050 ZSA comprise various road heads, a small portion of the Long Reef Golf Club clubhouse, and the Warringah Surf Rescue building (ignoring any relatively inerodible subsurfaces). The Florence Avenue road head and car park to the north, and road and car parking area east of the boat ramp (as far east as the Surf Rescue building), have some portion seaward of the Immediate ZSA (again ignoring any existing protective works).

Figure I12: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZSA) at northern end of Narrabeen Beach

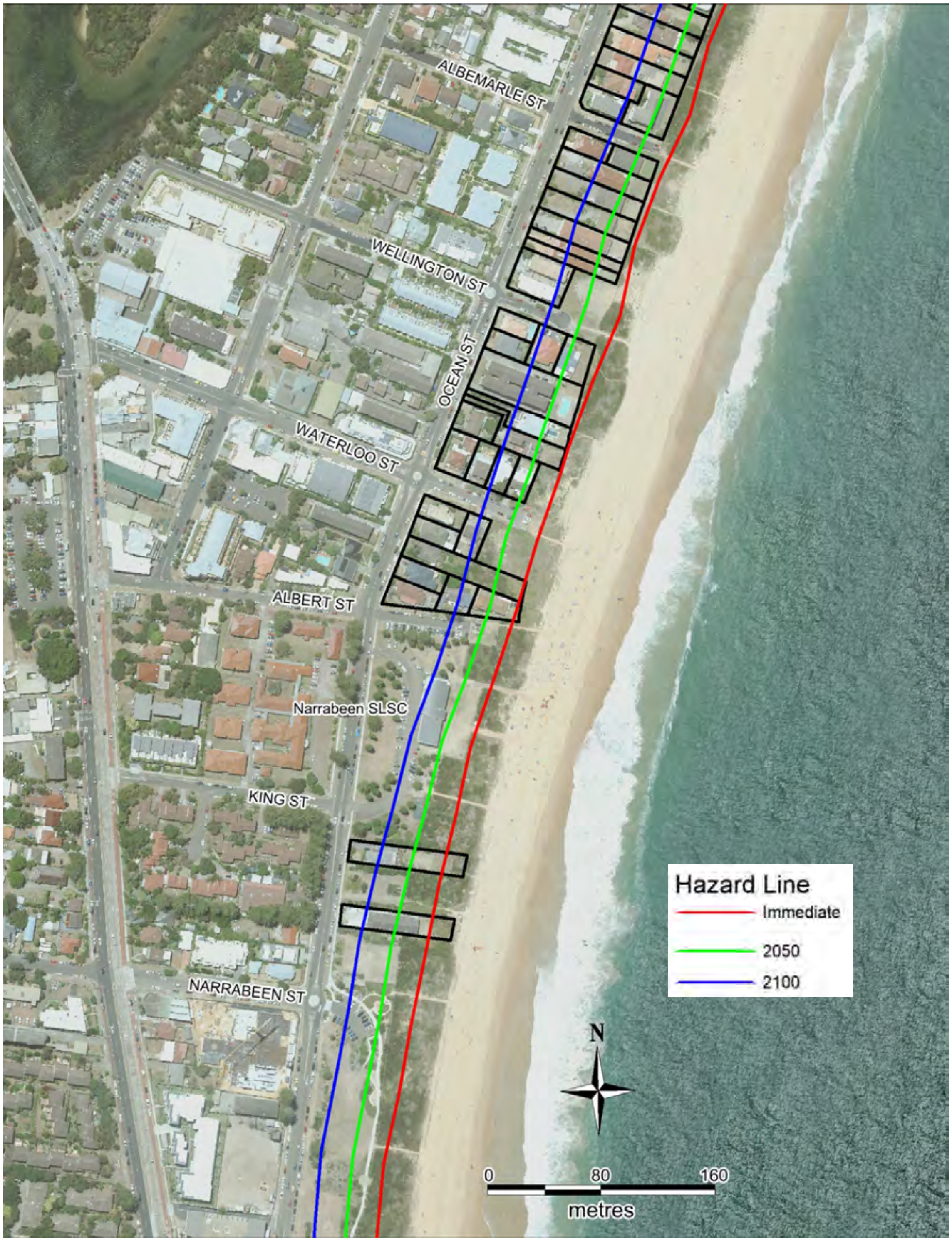

Figure I13: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZSA) near Narrabeen Street to Albemarle Street at southern end of Narrabeen Beach

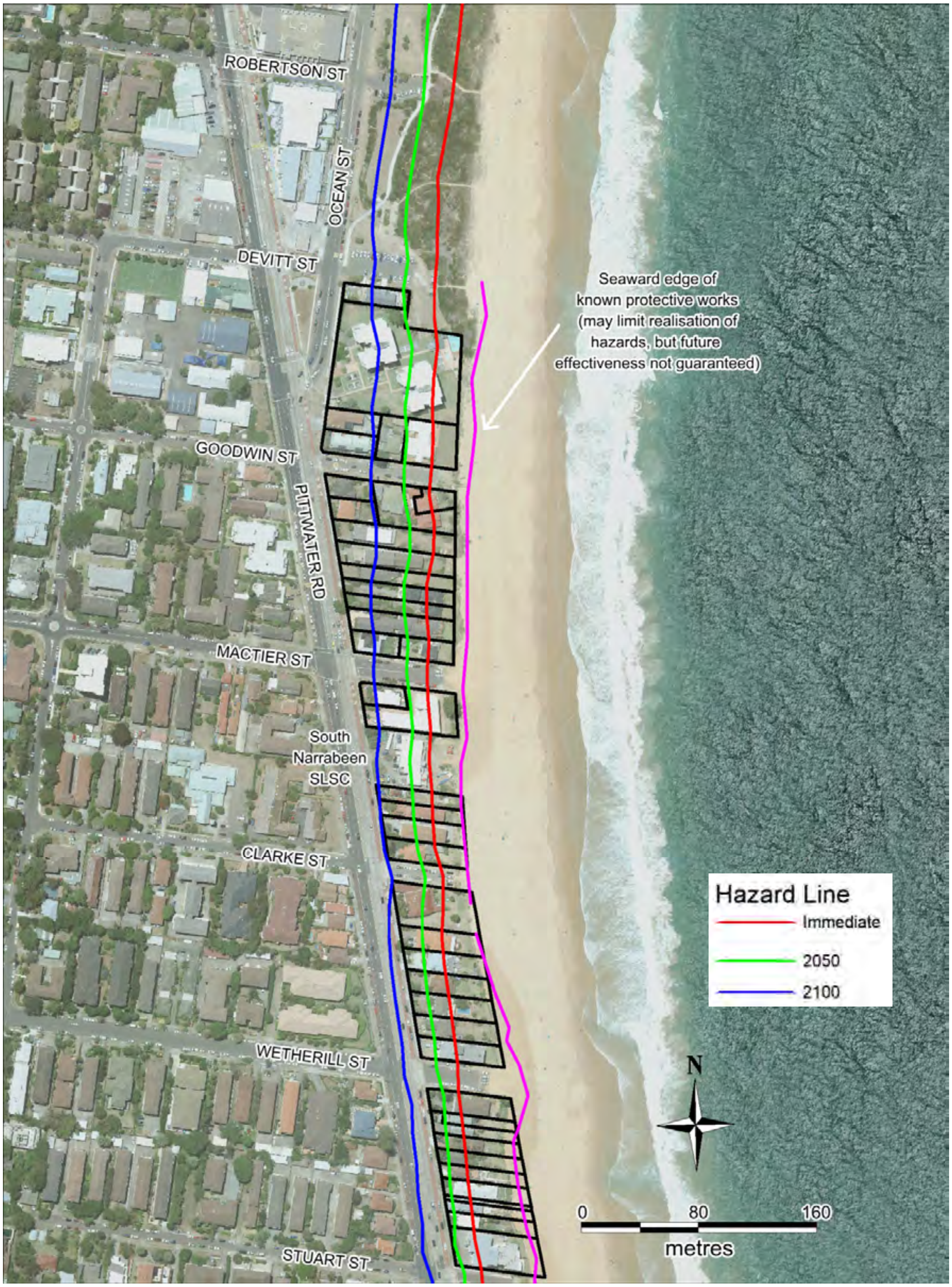

Figure I14: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZSA) from Stuart Street to Robertson Street at Collaroy-Narrabeen Beach

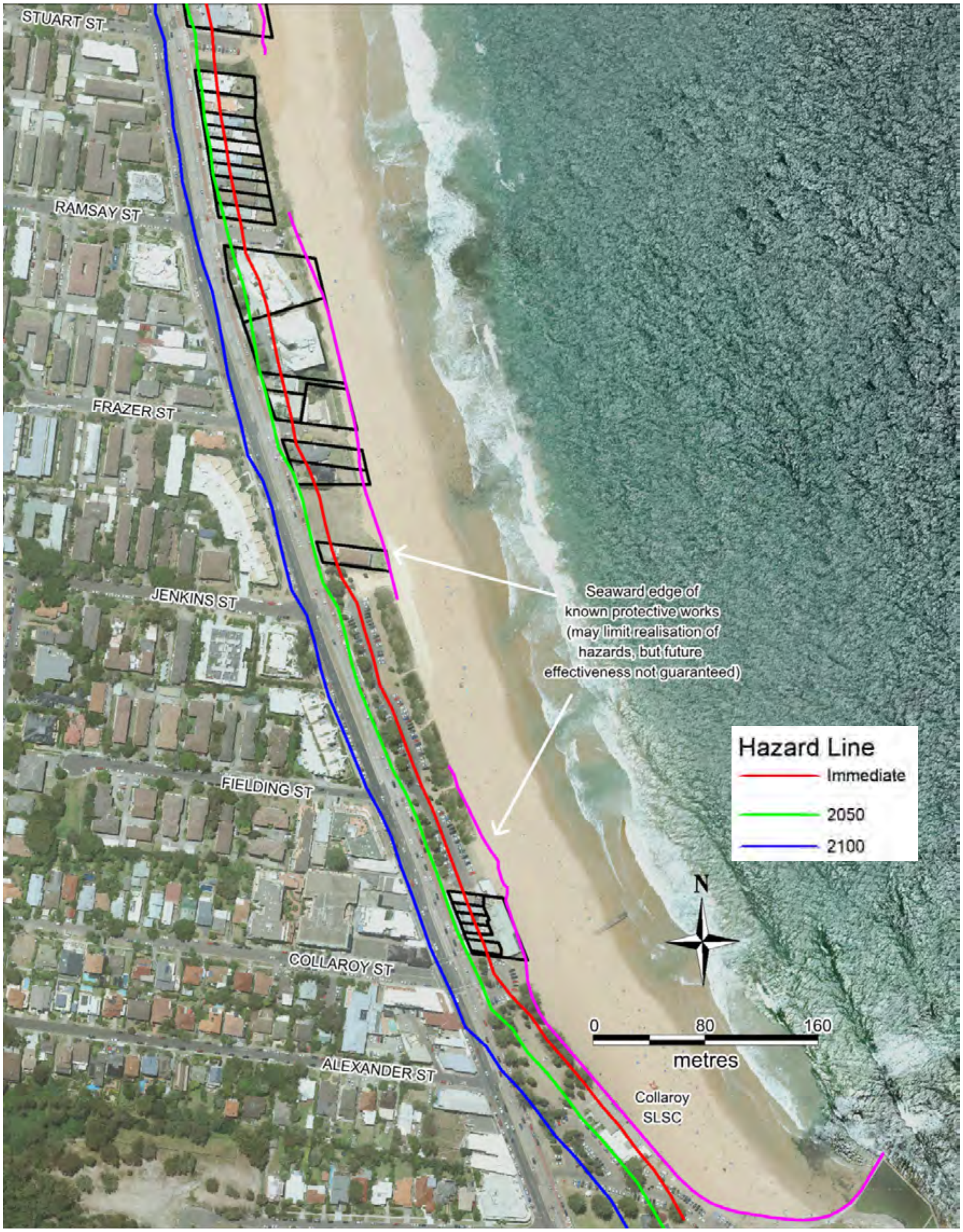

Figure I15: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZSA) at southern end of Collaroy Beach

Figure I16: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZSA) at Fishermans Beach

Figure I17: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZRFC) at northern end of Narrabeen Beach

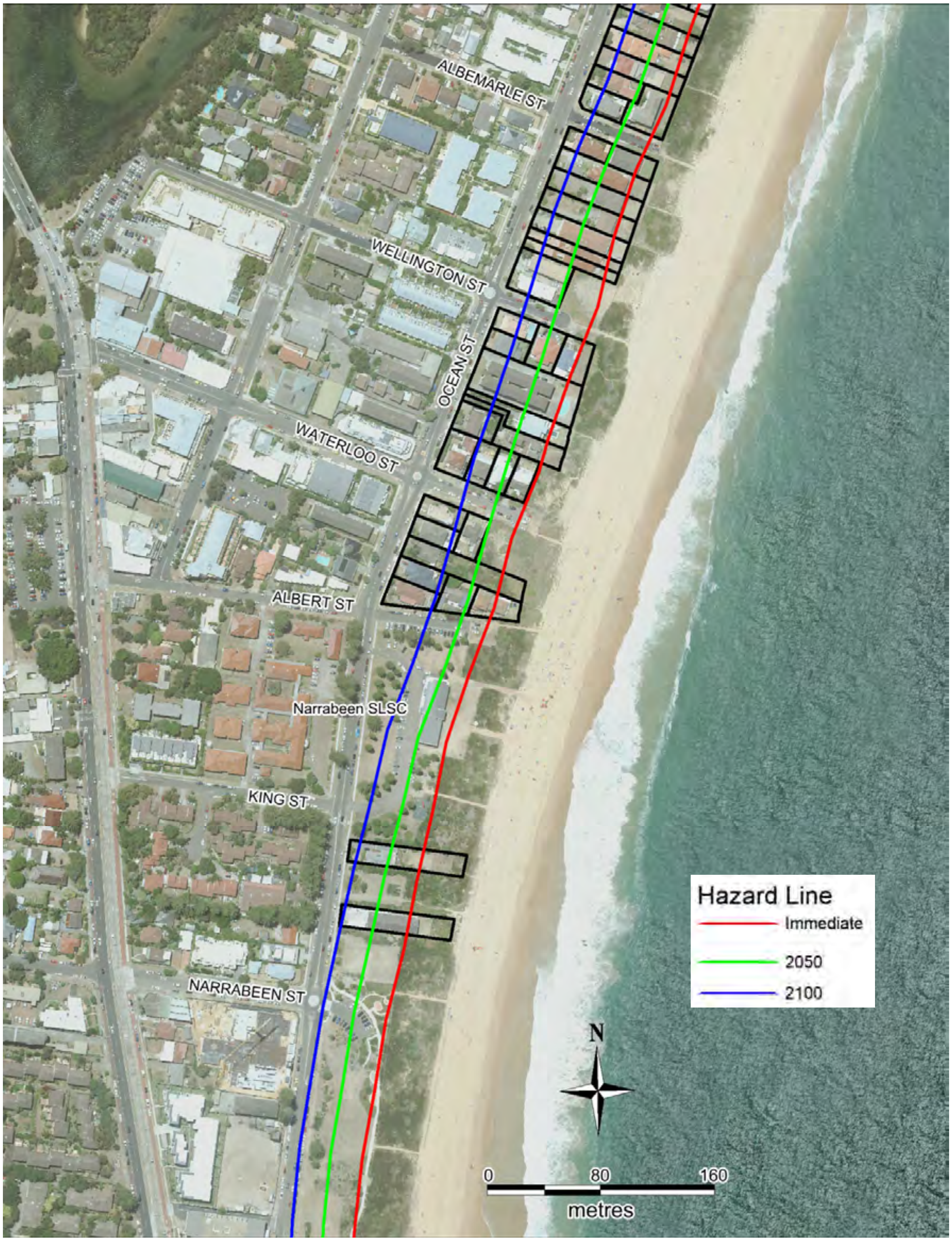

Figure I18: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZRFC) near Narrabeen Street to Albemarle Street at southern end of Narrabeen Beach

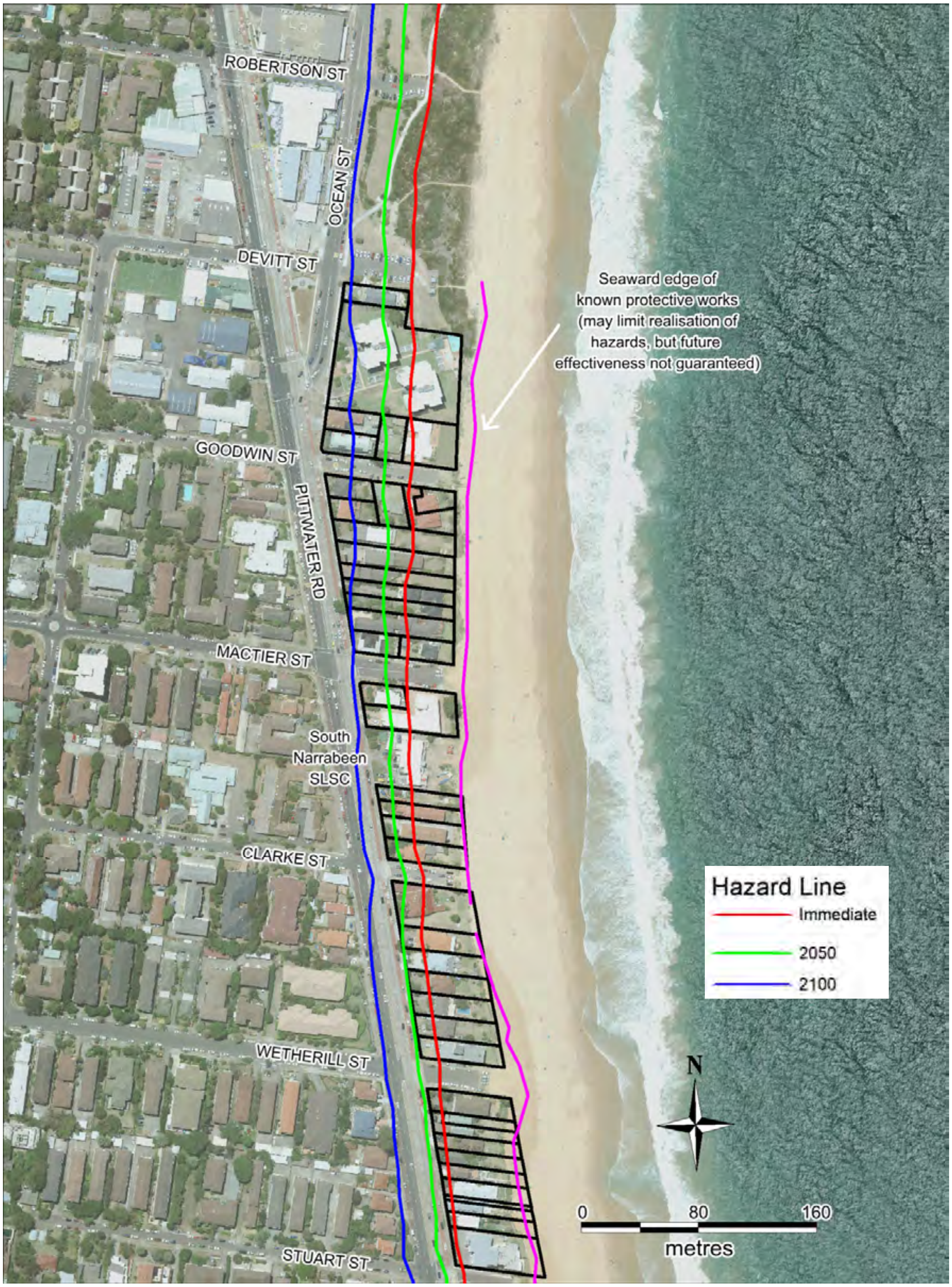

Figure I19: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZRFC) from Stuart Street to Robertson Street at Collaroy-Narrabeen Beach

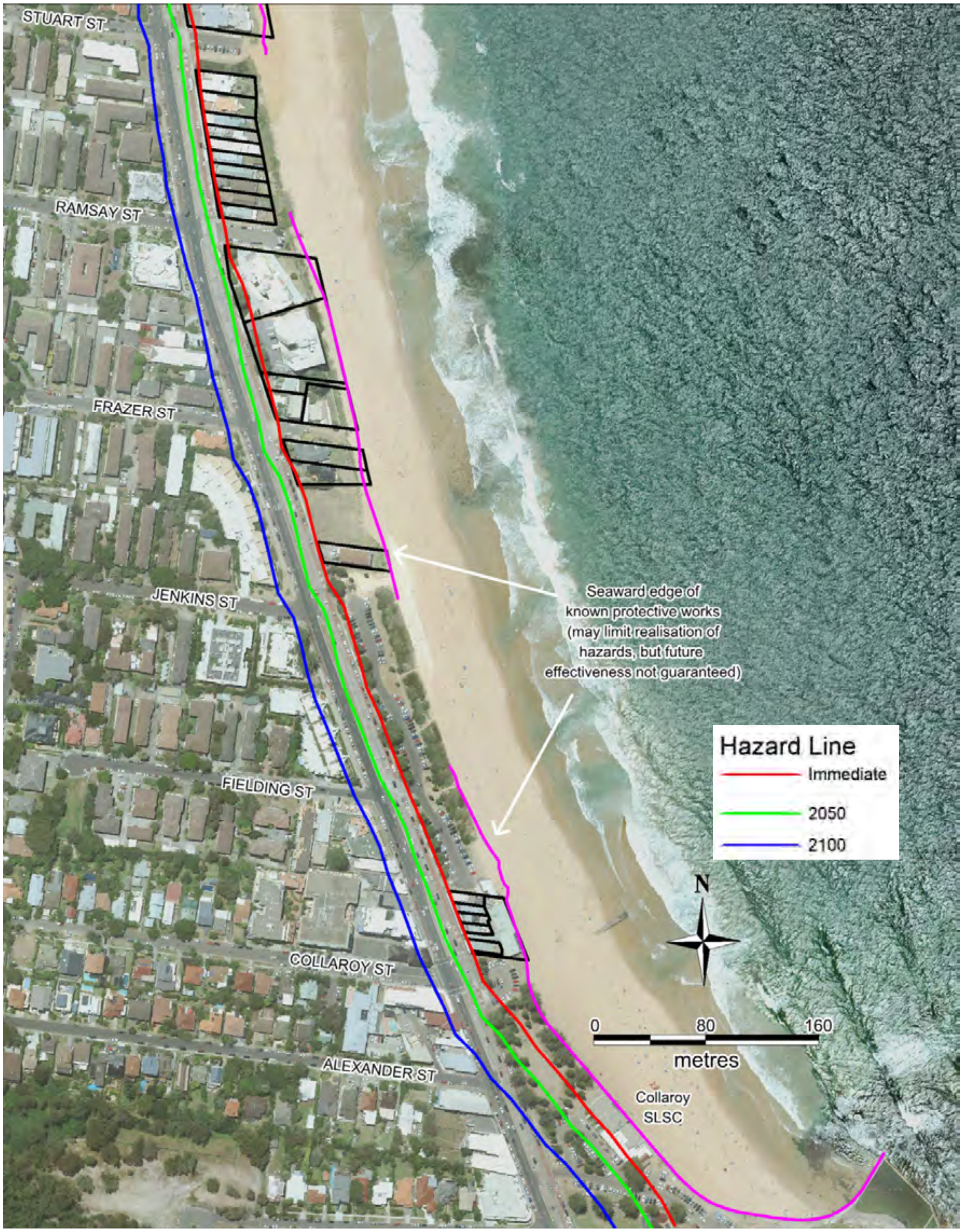

Figure I20: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZRFC) at southern end of Collaroy Beach

Figure I21: Immediate, 2050 and 2100 Coastline Hazard Lines (located at landward edge of ZRFC) at Fishermans Beach

Appendix J:
Estimation of Depth of Closure for Use in the Bruun Rule

CONTENTS

J1. INTRODUCTION

There are a number of methods to estimate the depth of closure for use in the Bruun Rule, as described in this Appendix. These include methods based on:

- wave characteristics (Section J2); and
- sedimentological data (Section J3).

A synthesis and discussion of the available methods is provided in Section J4, with estimation of the depth of closure for the study area provided in Section J5.

J2. METHODS BASED ON WAVE CHARACTERISTICS

Bruun (1988) suggested a depth of closure of $3.5H_b$, where H_b is the actual breaker height of the highest waves within a certain time period, namely 50 to 100 years according to Dubois (1992). However, Bruun (1988) also noted that a closure depth of $2H_b$ was appropriate for a Danish case study. For a 100 year ARI wave height of 8.5m (see **Appendix I**, Section I2.2), this is equivalent to closure depths of 17m to 30m.

Hallermeier (1981, 1983) defined three profile zones, namely the littoral zone, shoal or buffer zone[1], and offshore zone. This thus defined two closure depths, namely:

- an "inner" (closer to shore) closure depth at the seaward limit of the littoral zone, termed d_l by Hallermeier (1981) and d_s by Hallermeier (1983), and d_{inner} herein; and,
- an "outer" or "lower" (further from shore) closure depth at the seaward limit of the shoal/buffer zone, termed d_i by Hallermeier (1981) and d_o by Hallermeier (1983), and d_{outer} herein.

From Hallermeier (1981):

$$d_{inner} = 2.28H_e - 68.5\left(\frac{H_e^{\ 2}}{gT_e^{\ 2}}\right) \qquad (1)$$

where H_e is the effective significant wave height exceeded for 12 hours per year (that is, the significant wave height with a probability of exceedance of 0.137%), and T_e is similarly defined for wave period. Based on measured Sydney offshore wave data, H_e is about 5.6m and T_e is about 17s, and from Equation 1 the inner closure depth is thus about 12m.

From Hallermeier (1983):

$$d_{outer} = 0.018H_mT_m\sqrt{\frac{g}{D(s-1)}} \qquad (2)$$

where H_m and T_m are the median wave heights and periods respectively, D is the median sediment diameter (about 0.3mm in the study area), and S is the specific gravity of sand (about 2.6). Based on measured Sydney offshore wave data, H_m is about 1.5m and T_m is about 9.6s, and from Equation 2 the outer closure depth is thus about 37m.

In the *Coastal Risk Management Guide*, DECCW (2010b) recommended the use of the outer closure depth when using the Bruun Rule in the absence of readily available information on active profile slopes at a location under consideration.

Rijkswaterstaat (1987), approximating the work of Hallermeier (1978, 1981, 1983), found the following simplified estimate for the effective depth of closure (d_c), namely:

$$d_c = 1.75H_e \qquad (3)$$

Therefore, the predicted (inner) closure depth from Equation 3 is about 10m.

[1] Shoal zone in Hallermeier (1981) and buffer zone in Hallermeier (1983).

J3. METHODS BASED ON SEDIMENTOLOGICAL DATA

Sedimentological data consistently shows distinct changes in the characteristics of sediments with water depth offshore of NSW (Nielsen, 1994). These changes include variations in grain size, sorting, carbonate content and colour.

There are two distinctive sediment units immediately offshore of the NSW shoreline, namely Nearshore Sand, and (further offshore and coarser) Inner Shelf Sand (also known as Shelf Plain Relict or Palimpsest Sand). Nearshore Sand is further subdivided into Inner and Outer Nearshore Sand units.

For beaches fully exposed to the offshore wave climate, the boundary between Inner and Outer Nearshore Sands is typically found at about 11m to 15m depth (relative to AHD), while the boundary to the nearshore edge of Inner Shelf Sand is usually at 18m to 26m depth. The boundary between Nearshore Sands and Inner Shelf Sands corresponds to those parts of the seabed considered to be active and relict respectively. That is, there is no exchange of Nearshore Sands with those of the Inner Shelf.

Nielsen (1994) found that, based on a synthesis of field and laboratory data and analytical studies (particularly offshore of SE Australia), there were consistent limits of subaqueous beach fluctuations, namely water depths (relative to AHD) of:

- 12m ± 4m being the limit of significant wave breaking and beach fluctuations (consistent with the Inner/Outer Nearshore Sand Boundary and inner Hallermeier depth);
- 22m ± 4m being the absolute limit of sand transport under cyclonic or extreme storm events (consistent with the inshore Inner Shelf Sand boundary); and,
- 30m ± 5m being the limit of reworking and onshore transport of beach sized sand under wave action (consistent with the outer Hallermeier depth).

At Narrabeen, Nielsen (1994) noted that Inner Nearshore Sand extended down to -12m AHD, while Outer Nearshore Sand extended from there down to -22m AHD. Patterson Britton & Partners (1993) adopted similar values for Collaroy-Narrabeen Beach of -12m AHD and -23m AHD. Based on the seabed types depicted in Section 2.3 of the main report, Inner Nearshore Sand is evident down to about -17m AHD offshore of Collaroy Beach, and Inner Shelf Sand commenced at around -19 to -24m AHD[2].

[2] It is uncertain why Outer Nearshore Sands were not depicted offshore of Narrabeen Beach in the main report. Other authors, such as Hudson and Roy (1989), have identified Outer Nearshore Sands in this area.

J4. SYNTHESIS AND DISCUSSION

The methods based on wave characteristics (Section J2) and sedimentological data (Section J3) indicated “inner” closure depth values are in the order of 12m ± 4m in the study area, with “outer” closure depth values in the order of 35m.

Depth of closure is time-scale and space-scale dependent, and generally increases with time-scale (Capobianco et al, 1997). It is considered that although closure depths in the order of 35m may eventually be realised, this is more likely to be over time scales of centuries (ie beyond 2100). Therefore, it may be appropriate to adopt the “inner” Hallermeier depth for use in the Bruun Rule, which is expected to be in the range of 12m ± 4m in the study area, and can be defined to be at the boundary between Inner and Outer Nearshore Sand.

Aecom (2010), in a scoping study investigating the feasibility of undertaking beach nourishment in Sydney (with a particular focus on Collaroy-Narrabeen Beach as one of three beaches investigated in more detail), calculated the closure depth in three ways, namely:

- at the inshore boundary of the Inner Shelf Sand;
- at 22m water depth (relative to AHD); and,
- assuming a bed slope of 1:50.

The adopted closure depth was selected by Aecom (2010) based on the method that gave the shortest distance to the closure depth. The results obtained for beaches in the study area, including adopted inverse slopes for use in the Bruun rule, were as listed in Table J1. There is some uncertainty as to how the inverse slopes were derived.

Table J1: Closure depth and inverse slope in Bruun Rule estimated by Aecom (2010) for beaches in study area

Beach	Method	Closure depth (m AHD)	Inverse slope in Bruun Rule
Collaroy-Narrabeen	1:50 slope	18	52
Fishermans	sand boundary	5	45

J5. DETERMINATION OF CLOSURE DEPTH FOR STUDY AREA

As described in previous Sections, there are three depths that can be considered as closure depths for use in the Bruun Rule, namely:

- 12m ± 4m (consistent with the Inner/Outer Nearshore Sand boundary and inner Hallermeier depth);
- 22m ± 4m (consistent with the inshore Inner Shelf Sand boundary, and used by Aecom, 2010); and,
- 30m ± 5m (consistent with the outer Hallermeier depth).

Based on examination of Seabed Information Charts 82310-575 (Broken Bay) and 82310-576 (Sydney Heads) published by the Public Works Department in 1989 (see Section 2.3 of main report), inverse slopes for use in the Bruun Rule can be estimated as listed in Table J2. Note that the first three entries in the key to these charts in Section 2.3 of the main report correspond to Inner Shelf Sand, Outer Nearshore Sand and Inner Nearshore Sand respectively.

Table J2: Inverse slope in Bruun Rule estimated for beaches in study area based on three methods

Beach	Inverse slope in Bruun Rule		
	Inner Hallermeier	Nearshore Inner Shelf	Outer Hallermeier
Collaroy-Narrabeen	30	50	80
Fishermans	20	40	40

As noted in Section J4, it is considered to be reasonable to adopt inverse slopes for the Bruun Rule based on the "inner Hallermeier" method. If inverse slopes as per the "outer Hallermeier" method were realistic, it would be expected that long term recession due to sea level rise in the past would have been more detectable.

Appendix K:
Private Property Risk and Response Categories as per OEH (2013b)

CONTENTS

Page K

K1. INTRODUCTION

Based on "Guidelines for Preparing Coastal Zone Management Plans" OEH (2013b), there is a requirement to define "property risk" and "property response" categories for private property in the study area. This categorisation is tabulated in Section K2.

A description of the "property risk" categories is provided in Table K1.

Table K1: Property risk categories from OEH (2013b)

Risk Category	Description
1	Immediate Hazard Area (land seaward of the Immediate Hazard Line) covers at least 25% of lot
2	2050 Hazard Area (land seaward of the 2050 Hazard Line) covers at least 25% of lot
3	2100 Hazard Area (land seaward of the 2100 Hazard Line) covers at least 25% of lot
4[1]	2100 Hazard Area (land seaward of 2100 Hazard Line) covers part of lot but less than 25%

Where multiple risk categories applied at a particular lot, the numerically lower (that is, shorter planning period) risk category was adopted. The risk categories were determined for hazard lines defined using the landward edge of the Zone of Slope Adjustment (ZSA), ignoring existing protective works and non-sandy subsurfaces.

OEH (2013b) defined hazard lines including the Zone of Reduced Foundation Capacity (ZRFC). An opinion was obtained from the Department of Planning as to whether it was mandatory to include the ZRFC in hazard definition, and the advice received was:

> "a council can use its own judgement based on local circumstances to decide whether to include an allowance for reduced foundation capacity".

Therefore, it is considered to more appropriate and acceptable to define property risk categories using hazard lines defined at the landward edge of the ZSA (and not the ZRFC) since:

- the ZRFC is not an area that gets eroded or is necessarily attacked by waves; it is delineated to take account of the reduced bearing capacity of the sand adjacent to a slumped storm erosion escarpment;
- a structure located within the ZRFC (suitably founded) is not expected to impacted by erosion/recession coastal processes, either directly or indirectly, for a particular design event;
- it is not unusual for foundation conditions to be influenced by certain geotechnical conditions or proximity to natural hazards;
- inclusion of the ZRFC would trigger inclusion of additional properties into the study area, including some that are landward of Pittwater Road at Collaroy-Narrabeen Beach and landward of Seaview Parade at Fishermans Beach, which was considered to be overly conservative given realisation of hazards at these locations is barely credible over the next 50 to 100 years; and
- delineation of hazard lines at the landward edge of the ZSA has been traditional accepted coastal engineering practice for over 25 years.

A description of the property response" categories is provided in Table K2.

[1] Additional category adopted herein and not included in OEH (2013b), to capture additional lots with a small proportion of land seaward of the 2100 Hazard Line.

Table K2: Property response categories from OEH (2013b)

Response Category	Description
A	Coastal protection works considered technically feasible and cost effective - funding is being sought for implementation
B	Coastal protection works considered technically feasible but not cost-effective for public funding
C	Coastal protection works not considered technically feasible – no intended public authority works[2]

Given that Council has stated that it does not intend to fund any protective works at or seaward of private property, no lots in the study area could be given a Response Category of "A".

The term "technically feasible" was not defined in OEH (2013b), but has been defined herein consistently with the advice herein that protective works are only considered to be appropriate in the part of the study area south of Devitt Street at Collaroy-Narrabeen Beach, due to potential 'end effects' in other areas. Accordingly, the lots in the study area south of Devitt Street at Collaroy-Narrabeen Beach were defined as Response Category "B". In other areas (namely north of Devitt Street at Collaroy-Narrabeen Beach, and at Fishermans Beach), the Response Category was defined as "C".

[2] This category can appropriately be redefined adding the clause "and private works not generally recommended due to potential end effects on neighbouring properties".

K2. TABULATED CATEGORIES

The property risk and response categories for all lot addresses in the study area are listed in Table K3 (Fishermans Beach, 17 addresses) and Table K4 (Collaroy-Narrabeen Beach, 126 addresses), moving south to north in each case. Note that strata properties have additional individual addresses within the lot address listed.

Table K3: Property risk and response categories for all properties in study area at Fishermans Beach

Address	Risk Category	Response Category
1a Seaview Parade Collaroy 2097	3	C
1b Seaview Parade Collaroy 2097	3	C
1c Seaview Parade Collaroy 2097	3	C
1d Seaview Parade Collaroy 2097	3	C
1-3 Seaview Parade Collaroy 2097	2	C
5 Seaview Parade Collaroy 2097	2	C
7 Seaview Parade Collaroy 2097	1	C
11 Seaview Parade Collaroy 2097	1	C
1 Ocean Grove Collaroy 2097	1	C
3 Ocean Grove Collaroy 2097	1	C
5 Ocean Grove Collaroy 2097	4	C
9 Florence Avenue Collaroy 2097	1	C
7 Florence Avenue Collaroy 2097	2	C
5 Florence Avenue Collaroy 2097	4	C
8 Florence Avenue Collaroy 2097	3	C
6 Florence Avenue Collaroy 2097	4	C
29 Beach Road Collaroy 2097	3	C

Table K4: Property risk and response categories for all properties in study area at Collaroy-Narrabeen Beach

Address	Risk Category	Response Category
1058 Pittwater Road Collaroy 2097	1	B
1056 Pittwater Road Collaroy 2097	1	B
1060-1066 Pittwater Road Collaroy 2097	1	B
1096 Pittwater Road Collaroy 2097	1	B
1104 Pittwater Road Collaroy 2097	1	B
1106 Pittwater Road Collaroy 2097	1	B
1 Frazer Street Collaroy 2097	1	B
1110 Pittwater Road Collaroy 2097	1	B
1112 Pittwater Road Collaroy 2097	1	B
1114 Pittwater Road Collaroy 2097	1	B
1122 Pittwater Road Collaroy 2097	1	B
1126 Pittwater Road Collaroy 2097	1	B
1128 Pittwater Road Collaroy 2097	1	B
1130 Pittwater Road Collaroy 2097	1	B
1132 Pittwater Road Collaroy 2097	1	B
1134 Pittwater Road Collaroy 2097	1	B

Address	Risk Category	Response Category
1136 Pittwater Road Collaroy 2097	1	B
1138 Pittwater Road Collaroy 2097	1	B
1140 Pittwater Road Collaroy 2097	1	B
1142 Pittwater Road Collaroy 2097	1	B
1144 Pittwater Road Collaroy 2097	1	B
1150 Pittwater Road Collaroy 2097	1	B
1154 Pittwater Road Collaroy 2097	1	B
1156 Pittwater Road Collaroy 2097	1	B
1158 Pittwater Road Collaroy 2097	1	B
1160 Pittwater Road Collaroy 2097	1	B
1162 Pittwater Road Collaroy 2097	1	B
1164 Pittwater Road Collaroy 2097	1	B
1166a Pittwater Road Collaroy 2097	1	B
1166b Pittwater Road Collaroy 2097	1	B
1168 Pittwater Road Collaroy 2097	1	B
1172 Pittwater Road Narrabeen 2101	1	B
1174 Pittwater Road Narrabeen 2101	1	B
1176 Pittwater Road Narrabeen 2101	1	B
1178 Pittwater Road Narrabeen 2101	1	B
1180 Pittwater Road Narrabeen 2101	1	B
1182 Pittwater Road Narrabeen 2101	1	B
1186 Pittwater Road Narrabeen 2101	1	B
1190 Pittwater Road Narrabeen 2101	1	B
1192 Pittwater Road Narrabeen 2101	1	B
1194 Pittwater Road Narrabeen 2101	1	B
1196 Pittwater Road Narrabeen 2101	1	B
1204 Pittwater Road Narrabeen 2101	1	B
1206 Pittwater Road Narrabeen 2101	3	B
1a Mactier Street Narrabeen 2101	1	B
1210 Pittwater Road Narrabeen 2101	3	B
1214 Pittwater Road Narrabeen 2101	2	B
1216 Pittwater Road Narrabeen 2101	2	B
1218 Pittwater Road Narrabeen 2101	2	B
1220 Pittwater Road Narrabeen 2101	2	B
1222 Pittwater Road Narrabeen 2101	2	B
2 Goodwin Street Narrabeen 2101	1	B
2a Goodwin Street Narrabeen 2101	1	B
4 Goodwin Street Narrabeen 2101	3	B
1224 Pittwater Road Narrabeen 2101	4	B
1226 Pittwater Road Narrabeen 2101	4	B
1 Goodwin Street Narrabeen 2101	1	B
5 Goodwin Street Narrabeen 2101	3	B
1228 Pittwater Road Narrabeen 2101	4	B
9 Ocean Street Narrabeen 2101	4	B
11 Ocean Street Narrabeen 2101	2	B
23 Ocean Street Narrabeen 2101	3	B

Address	Risk Category	Response Category
81 Ocean Street Narrabeen 2101	2	C
87 Ocean Street Narrabeen 2101	2	C
9 Albert Street Narrabeen 2101	2	C
7 Albert Street Narrabeen 2101	3	C
95 Ocean Street Narrabeen 2101	3	C
4 Waterloo Street Narrabeen 2101	3	C
3 Waterloo Street Narrabeen 2101	2	C
5 Waterloo Street Narrabeen 2101	3	C
105 Ocean Street Narrabeen 2101	2	C
107 Ocean Street Narrabeen 2101	2	C
109 Ocean Street Narrabeen 2101	2	C
2 Wellington Street Narrabeen 2101	2	C
4 Wellington Street Narrabeen 2101	3	C
115 Ocean Street Narrabeen 2101	4	C
117 Ocean Street Narrabeen 2101	3	C
117a Ocean Street Narrabeen 2101	3	C
119 Ocean Street Narrabeen 2101	3	C
121 Ocean Street Narrabeen 2101	3	C
123 Ocean Street Narrabeen 2101	3	C
125 Ocean Street Narrabeen 2101	3	C
2 Albemarle Street Narrabeen 2101	2	C
127 Ocean Street Narrabeen 2101	4	C
1 Albemarle Street Narrabeen 2101	2	C
129 Ocean Street Narrabeen 2101	4	C
131 Ocean Street Narrabeen 2101	4	C
133 Ocean Street Narrabeen 2101	3	C
135 Ocean Street Narrabeen 2101	3	C
137 Ocean Street Narrabeen 2101	3	C
139 Ocean Street Narrabeen 2101	3	C
2 Loftus Street Narrabeen 2101	2	C
4 Loftus Street Narrabeen 2101	3	C
141 Ocean Street Narrabeen 2101	4	C
143 Ocean Street Narrabeen 2101	4	C
145 Ocean Street Narrabeen 2101	3	C
147 Ocean Street Narrabeen 2101	3	C
149 Ocean Street Narrabeen 2101	3	C
151 Ocean Street Narrabeen 2101	3	C
153a Ocean Street Narrabeen 2101	2	C
155 Ocean Street Narrabeen 2101	2	C
157 Ocean Street Narrabeen 2101	3	C
2 Octavia Street Narrabeen 2101	2	C
159a Ocean Street Narrabeen 2101	3	C
161 Ocean Street Narrabeen 2101	3	C
163 Ocean Street Narrabeen 2101	3	C
165 Ocean Street Narrabeen 2101	3	C
167 Ocean Street Narrabeen 2101	3	C

Address	Risk Category	Response Category
169 Ocean Street Narrabeen 2101	3	C
171 Ocean Street Narrabeen 2101	3	C
2 Tourmaline Street Narrabeen 2101	3	C
173 Ocean Street Narrabeen 2101	4	C
1 Tourmaline Street Narrabeen 2101	2	C
179 Ocean Street Narrabeen 2101	3	C
181 Ocean Street Narrabeen 2101	3	C
183 Ocean Street Narrabeen 2101	3	C
185 Ocean Street Narrabeen 2101	3	C
189 Ocean Street Narrabeen 2101	3	C
191 Ocean Street Narrabeen 2101	3	C
1 Emerald Street Narrabeen 2101	2	C
193 Ocean Street Narrabeen 2101	4	C
195a Ocean Street Narrabeen 2101	2	C
197 Ocean Street Narrabeen 2101	3	C
203 Ocean Street Narrabeen 2101	4	C
205 Ocean Street Narrabeen 2101	4	C
209-211 Ocean Street Narrabeen 2101	4	C

Appendix L:
Risk Assessment to Define Appropriate Development Setbacks and Controls

CONTENTS

Page L

L1. INTRODUCTION

L1.1 Background

Coastal development setbacks in NSW have traditionally been defined through delineation of coastal hazard lines, using a variety of planning periods and hazard zones. However, there has been no known rigorous assessment of the validity of traditional hazard lines in terms of leading to an acceptable risk to property if used as setbacks for new development.

For the Collaroy-Narrabeen Beach and Fishermans Beach CZMP, it was agreed between the study team, Council staff, Councillors,Office of Environment and Heritage (OEH) staff[1] and an external peer reviewer (Mr Bruce Walker of JK Geotechnics) that defining appropriate development setbacks using an acceptable risk approach was valid, reasonable and an improvement on traditional hazard line approaches to defining setbacks.

L1.2 Scope

The ‘acceptable risk’ setbacks developed herein are based on coastal erosion caused by meteorological events (“coastal storms”) leading to large waves and elevated water levels, and recession due to net sediment loss and sea level rise . Tsunamis, which have rarer frequencies of occurrence and different driving processes to coastal storms[2], have not been considered.

L1.3 Framework

Accordingly, the adopted acceptable risk approach is outlined in the Appendix herein. The framework of the adopted approach came from the Australian Geomechanics Society (AGS) procedures for landslide risk management (AGS, 2007a, b), which were developed over a period of more than a decade via a Working Group of experts[3], and have been widely applied in geotechnical engineering practice since 2000[4]. The AGS procedures were also subject to peer review and discussion through the AGS Landslides Taskforce, with 23 members. That is, the AGS procedures can be considered to be an established, recognised and peer reviewed methodology for defining landslide risk for development assessment. With modification to be appropriate for “sandy beach” coastal hazards, it is considered that the same principles of the AGS procedures can be applied to define acceptable risk for beachfront development, as has been undertaken herein.

L1.4 Recognition of Uncertainty

It is important to recognise that future climate cannot be predicted precisely, and is subject to not only storm variability, but longer term cycles such as the El Nino / La Nina Southern Oscillation, Pacific Decadal Oscillation, and Interdecadal Pacific Oscillation (IPO). Helman (2007) has postulated that during negative Interdecadal Pacific Oscillation (IPO) phases, the NSW coast experiences wet periods, major floods, sea level above the long term trend and coastal erosion. Using an 11 year

[1] Including Mr Daylan Cameron and Mr Mark Moratti. Kinsela and Hanslow (2013), authored by two OEH staff, have recently noted support for such an approach.
[2] Tsunamis are typically driven by earthquakes, landslides, large scale collapse of volcanic islands, or asteroid impacts, with earthquakes being the dominant tsunami source in NSW for events more frequent than 500 year average recurrence interval (Somerville et al, 2009).
[3] Mr Bruce Walker, who peer reviewed the document herein, was the Working Group Convenor.
[4] Using preceding AGS documents as discussed in AGS (2007a).

Chebychev filter annual series from 1871 to 2008 (Folland, 2008), a significant past continuous negative IPO period was from 1945 to 1977, and IPO was positive from 1978 to 2000, returning to negative from 2001 to 2008 (although the nature of the filtering was such that the 2004 to 2008 period should be regarded with caution). A return to negative IPO combined with additional future projected sea level rise could lead to a future period of enhanced erosion compared to the 1978 to 2000 period.

Future climate can also not be predicted precisely due to ongoing climate change caused by the greenhouse effect. Climate change effects such as sea level rise are projected by researchers based on various scenarios as to how greenhouse gases and aerosols will be emitted anthropogenically in the future, that is so called "representative concentration pathways" as described by the Intergovernmental Panel on Climate Change (IPCC), for example in IPCC (2013a). These scenarios represent a range of 21st century climate policies and cannot be precisely predicted as they largely depend on political decisions and economic growth.

Furthermore, storm events more severe than adopted design events can occur, or a structure could remain in place for longer than the design life considered herein (thus potentially being exposed to more severe conditions, for example because sea level rise is projected to be ongoing).

Therefore, it must be recognised that any development landward of a particular "acceptable risk" line is not at zero risk (but at acceptably low risk), and damage may be possible both during and particularly beyond the design life. Council should not (and could not) guarantee that development given consent to be sited landward of a particular "acceptable risk" line would never be damaged by coastal processes.

That stated, the approach developed herein is considered to be reasonable and valid for defining acceptable risk to property for new development in the study area, and an improvement on traditional methods of hazard definition. It is recommended that the CZMP is updated at least every 10 years to enable improved understanding to be incorporated as required.

L1.5 Risk to Life

Only risk to property is evaluated herein. In the coastal beach context, risk to life related to development in the study area was considered to be acceptably low as:

- coastal storms (large waves and elevated water levels) are generally foreseeable at least 24 hours in advance, with warnings issued by the Bureau of Meteorology;
- a large component of elevated water levels is astronomical tide, which can be accurately predicted decades into the future;
- erosion would generally be expected to be greatest for a few hours near the peak of the tide;
- the progress of erosion on a beach is visible and perceptible, and would not generally be expected to proceed undetected to damage development;
- it is highly unlikely that a landowner would be occupying a dwelling and would be unaware (or would not have been made aware) that this dwelling was at imminent threat of damage;
- the State Emergency Service (SES), if mobilised, has powers to warn and evacuate residents if required (as does NSW Police); and
- Council could request the SES taking on a Combat Agency role if an actual emergency was occurring and it had not already been mobilised.

These factors mean that residents would have a low probability of occupancy and/or loss of life during an actual storm event that could threaten development, and hence have a low risk to life which would satisfy the acceptance criteria given in AGS (2007a).

L1.6 Appendix Structure

The Appendix herein is set out as follows:

- design life is considered in Section L2;
- in Section L3 to L6, risk is considered in the context of ignoring existing protective works (such as seawalls and revetments) and non-sandy subsurfaces:
    - risk is defined as the product of likelihood and consequences, with likelihood discussed in Section L3 and consequences (on a structure situated immediately landward of a particular setback position) outlined in Section L4;
    - acceptable risk is defined in Section L5;
    - likelihood lines are delineated for the study area in Section L6, including comparison to traditional hazard lines;
- consideration of the effects of existing protective works (as are present along much of Collaroy-Narrabeen Beach south of Devitt Street) is made in Section L7;
- consideration of non-sandy subsurfaces (as occur at Fishermans Beach) is made in Section L8;
- plots of the determined acceptable risk lines are provided in Section L9;
- the implications of these acceptable risk lines on development controls are outlined in Section L10; and
- discussion on other approaches to risk determination are provided in Section L11.

Note that all aerial photography depicted herein was captured on 29 January 2011.

L2. DESIGN LIFE

The risk assessment must be undertaken in the context of a specified design life. This design life governs the planning period over which risks are assessed. That is, risks to structures will be determined as being acceptable or not acceptable on the basis of the risk of damage to the structure at the end of the design life.

Selection of a suitable design life is discussed in Section 9 of AGS (2007a) and Section C9.3 of AGS (2007b), in which it is noted that:

- a design life of at least 50 years would be considered to be reasonable for permanent structures used by people; and
- there is a community expectation that a residential dwelling frequently, with appropriate maintenance, will have a functional life well in excess of 50 to 60 years.

The design life of a structure should be related to the typical design life of its components, such as concrete, steel, masonry and timber. The design life used in various Australian Standards is as follows:

- in *AS 3600*, a 50 years ± 20% design life[5] (that is, 40 year to 60 years) is used in devising durability requirements for concrete structures;
- in *AS 2870*, for design purposes the life of a structure is taken to be 50 years for residential slabs and footings construction;
- in *AS 1170.0*, the design life for normal structures is generally taken as 50 years[6]; and
- in *AS 4678*, the design life for earth-retaining structures (structures required to retain soil, rock and other materials) is noted as 60 years for river and marine structures and residential dwellings.

The cost of new residential development is amortised for tax purposes over 40 years based on Subdivision 43-25 of the *Income Tax Assessment Act 1997*.

Based on the above, it is considered that a reasonable design life to adopt for devising setbacks and controls for beachfront development in the study area is between 40 and 60 years. Given the uncertainty in future climate, it is considered to be more appropriate to choose the upper end of this range, and hence a design life of 60 years has been adopted herein[7]. The design life has been applied in 2014, and thus 2074 represents the end of the design life.

A landowner may choose to design a structure for a longer design life, in which case a site specific risk assessment could be completed by the applicant to define acceptable risks over the selected life. It should also be recognised that future development applications (after 2014) that reference the acceptable risk lines developed herein would be applying a design life of less than 60 years. On this

[5] Period for which a structure or a structural member is intended to remain fit for use for its intended purpose with appropriate maintenance.

[6] In AS 1170.0, it is noted that for a design life of 50 years and normal structures (Importance Level 2), design event probabilities for structural actions should be 500 year ARI for wind, 150 year ARI for snow and 500 year ARI for earthquake.

[7] Note that for beachfront development in the Pittwater Council Local Government Area, "development must be undertaken in accordance with the acceptable risk management criteria defined in this document [the "Coastline Risk Management Policy for Development In Pittwater", which is Appendix 6 of the Pittwater 21 Development Control Plan] for a design project life, taken to be 100 years, unless otherwise justified by the applicant and acceptable to Council". That is, this is an example of a Council that has adopted a more conservative design life than 60 years, namely 100 years.

basis, it is recommended that applicants in the study area be required to obtain coastal engineering advice to ensure that acceptable risk has been addressed over a 60 year design life at the time of any development application.

An action recommended in the CZMP herein is also for the document to be updated at least every 10 years. This would enable the acceptable risk lines to remain relevant as understanding of coastal processes and climate change (such as sea level rise) develops in the future.

L3. LIKELIHOOD (IGNORING EXISTING PROTECTIVE WORKS AND NON-SANDY SUBSURFACES)

L3.1 AGS Terminology

AGS (2007a, b) used 6 likelihood descriptors, as set out in Column 1 of Table L1[8], along with associated annual exceedance probabilities (AEPs). The AEP is given as both the indicative (single) value reported by AGS (2007a, b) in Column 2, as well as the range (based on notional boundaries between the likelihoods) in Column 3.

For a design life of 60 years, the cumulative probability of an event of that AEP occurring at least once over the design life was determined as per Column 4 of Table L1, using the formula[9]:

$$J = 1 - (1 - P)^L \tag{1}$$

where *P* is the AEP, *L* is the design life (years) and *J* is the probability of the event with an AEP of *P* occurring over the design life. The lower probability limit was associated with each descriptor herein, as per Column 5 of Table L1, which is conservative.

Table L1: Likelihood descriptors and associated probabilities used by AGS (2007a, b)

1 Descriptor	2 Annual Exceedance Probability (indicative value)	3 Annual Exceedance Probability	4 Cumulative probability of event occurring over design life (range)	5 Designated cumulative probability of event occurring over design life
Almost Certain	10%	> 5%	> 95.4%	95.4%
Likely	1%	0.5 to 5%	26.0 to 95.4%	26%
Possible	0.1%	0.05 to 0.5%	3.0 to 26.0%	3%
Unlikely	0.01%	0.005 to 0.05%	0.3 to 3.0%	0.3%
Rare	0.001%	0.0005 to 0.005%	0.03 to 0.3%	0.03%
Barely Credible	0.0001%	< 0.0005%	< 0.03%	not used

L3.2 Long Term Scenarios Considered

For sea level rise and long term recession , three scenarios have been considered herein, namely:

- a “mild case” estimate, taken to have a 95% probability of exceedance (leading to lower recession);
- a “best” estimate, taken to have a 50% probability of exceedance; and
- a “severe case” estimate, taken to have a 5% probability of exceedance (leading to higher recession).

Calculations to determine the magnitude of the long term recession and rotation associated with each of the three scenarios are provided in Sections L3.3.4, L3.3.5 and L3.3.7. Storm demand and the

[8] The heading of each column shows the column number.
[9] For example see Laurenson (1987).

spatial extent of erosion, which were not determined in this scenario based manner, are considered in Section L3.3.1 and Section L3.3.3 respectively.

L3.3 Coastal Hazard Line Components

L3.3.1 Storm Demand

During storms, large waves, elevated water levels and strong winds can cause severe erosion to sandy beaches. Storm demand represents the volume of sand removed from a beach (defined herein as the volume lost above 0m AHD) that could be expected due to a severe storm or from a series of closely spaced storms.

Based on measurements at NSW beaches, Gordon (1987) derived relationships between storm demand and average recurrence interval, in both “high demand” (at rip heads) and “low demand” (away from rip heads) areas. He estimated that the storm demand above 0m AHD was about 223m^3/m for the 100 year average recurrence interval (ARI) event, for exposed NSW beaches at rip heads, and depicted a relationship between storm demand (plotted vertically) and the logarithm of ARI (plotted horizontally) that was linear (Figure L1).

For the investigation reported herein and consistent with Geomarine (1991) and WorleyParsons (2009), the 100 year ARI storm demand at Collaroy-Narrabeen Beach (north of Frazer Street) was adopted as 250m^3/m, which is a more conservative value. The blue curve in Figure L1 represents this relationship for a range of ARI’s[10]. South of Frazer Street, the 100 year ARI storm demand was adopted as reducing linearly down to 200m^3/m at Collaroy Services Beach Club and then linearly reducing down to 150m^3/m south of Collaroy SLSC (not depicted in Figure L1), as per WorleyParsons (2009), and also see **Appendix I**.

For Fishermans Beach, a 100m^3/m storm demand was adopted, as per WorleyParsons (2009), and also see **Appendix I**. The red curve in in Figure L1 represents this relationship for a range of ARI’s[11].

It is recognised that it has been assumed that the wave climate is stationary in this procedure, and that wave heights and directions may change in the future (compared to the past) under climate change. However, it is considered that insufficient information is presently available to enable any reliable estimation of what these changes may be. Conservative allowances for beach rotation have been included in the analysis (see Section L3.3.7) to take some account of this future uncertainty. In addition, as noted previously, the CZMP should be regularly reviewed.

Woodroffe et al (2012) considered potential variations to storm wave direction and height in probabilistically assessing future recession at Narrabeen Beach, and did not find significant effects in the scenarios assessed.

[10] Factoring up Gordon (1987) by 250÷223=1.12, where 223m^3/m is the 100 year ARI storm demand value from Gordon (1987).
[11] Factoring down Gordon (1987) by 100÷223=0.45, where 223m^3/m is the 100 year ARI storm demand value from Gordon (1987).

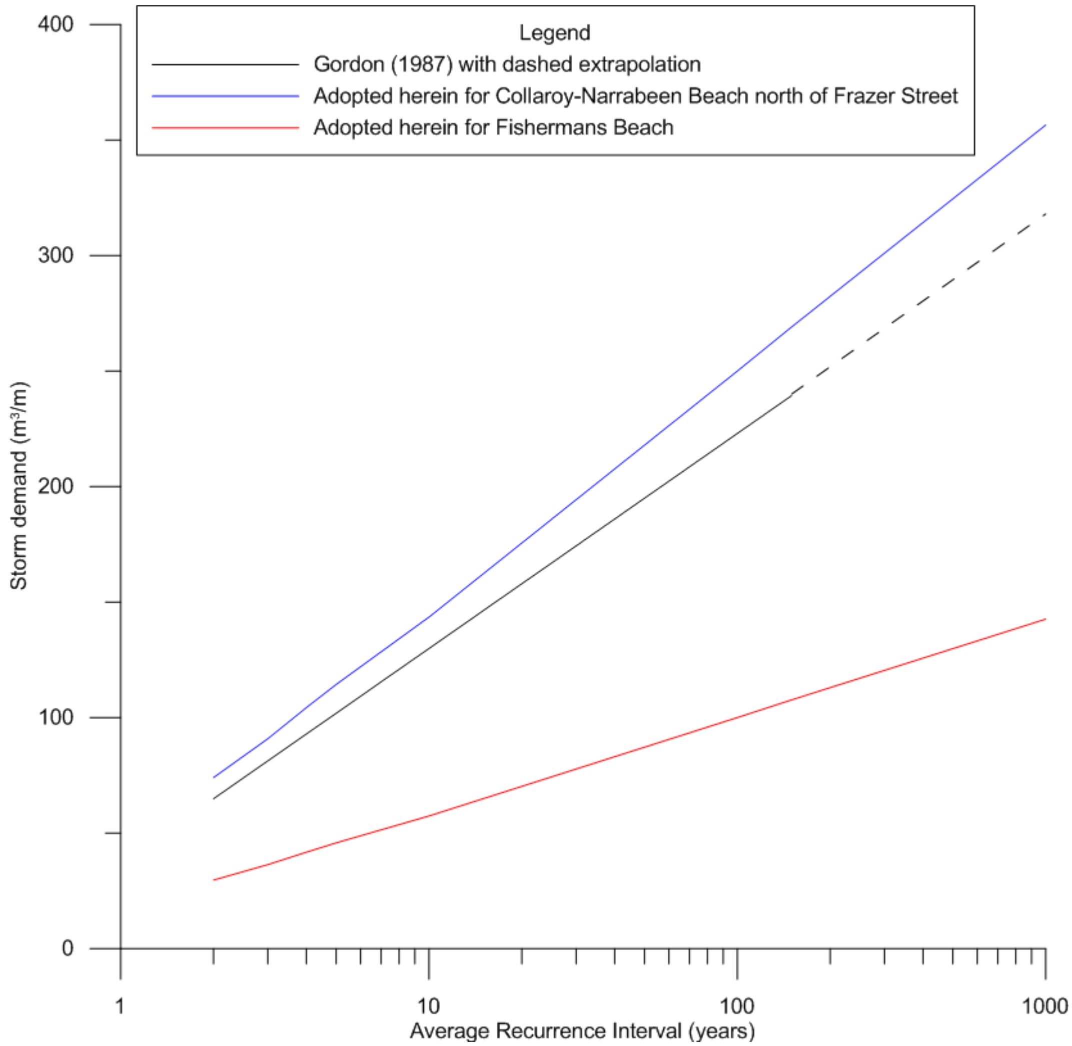

Figure L1: Relationship between storm demand and ARI as developed by Gordon (1987) for "high demand" (rip head) areas, along with adopted values for investigation herein

As noted by Woodroffe et al (2012), coastal zone managers are increasingly seeking beach erosion hazard (storm demand) predictions within a probabilistic framework to facilitate risk informed decision making.

Callaghan et al (2008, 2009) developed a method for estimation of storm demand based on joint probability distributions of wave height, storm duration, wave period, tidal anomaly, and wave direction, a so-called Joint Probability Method (JPM) . It can be inferred from these papers that 100 year ARI storm demand values at Narrabeen Beach (near Narrabeen Street) using this JPM were in the order of 220m^3/m to 250m^3/m, consistent with the values adopted herein. However, there was uncertainty in extrapolating their results to such rare events.

Callaghan et al (2013) extended the original Callaghan et al (2008, 2009) papers with consideration of two additional storm erosion models, and other developments. They noted an expectation that there was an upper limit to beach erosion on the basis that there was a finite amount of energy available to drive geophysical systems (atmospheric events generating erosion). For the best fitting model, the relationship between storm demand and the logarithm of ARI was found to be linear as per Gordon (1987), up to 1,000 year ARI, although it was considered that a downward concave tail was the most physically realistic. On this basis, adopting a straight line tail as per Figure L1 is likely to be conservative.

There is a "self-limiting" characteristic to beach erosion in that as sand is removed from the upper beach it tends to deposit in offshore bars, which reduces the wave energy reaching the beach. That is, beaches in an eroded state have lower storm demands due to dissipation of wave energy on offshore bars formed during previous erosion events (Harley et al, 2009)[12]. This is evident with the logarithmic horizontal axis in Figure L1.

L3.3.2 Application of Storm Demand to Beach Profiles

Throughout the Appendix herein, 2006 profiles were used as the base (pre-storm) profiles, with the storm demand volume removed from each photogrammetric profile using the method of Nielsen et al (1992) to determine the position (landward edge) of the Zone of Slope Adjustment (see **Appendix I** for further explanation).

In the method of Nielsen et al (1992), a ϕ value (angle of repose of sand) of 35° was adopted. Kinsela and Hanslow (2013) have suggested that a risk averse approach would be to consider a range of ϕ values between 30° and 35°. However, note that (for example) for a 6m AHD dune elevation, the difference in Zone of Slope Adjustment position over this ϕ range is only 0.6m, with lower ϕ values giving further landward positions[13].

Effects of the order of 1m in magnitude are not of significance herein. Furthermore, borehole data has indicated that a ϕ value of 35° is likely to be reasonable for the study area. Therefore, no allowance was made for variability in ϕ values herein.

L3.3.3 Spatial Extent of Erosion

Although the entire beach is unlikely to be eroded uniformly (erosion tends to be concentrated at rip heads, which are typically a few hundred metres apart), it was conservatively assumed that all locations in the study area would be equally likely to be eroded in any particular storm.

L3.3.4 Long Term Recession Due to Net Sediment Loss

Three scenarios were considered and applied at both Collaroy-Narrabeen Beach and Fishermans Beach for long term recession due to net sediment loss , namely:

- a "mild case" estimate (95% probability of exceedance) of zero;
- a "best" estimate (50% probability of exceedance) of 0.05m/year as per the mid-range value in WorleyParsons (2009) and as adopted in **Appendix I**; and
- a "severe case" estimate (5% probability of exceedance) of 0.1m/year as per the high-range value in WorleyParsons (2009).

[12] Or to state it in a different way, relatively more wave energy is required to erode an already eroded beach (Yates et al, 2009).
[13] For a 10m dune elevation the difference is 1.2m, and for a 4m dune elevation the difference is 0.3m.

These rates were derived from analysis of photogrammetric data for dates from 1941 to 2006, as discussed in **Appendix I**. The rates were assumed to be constant over the design life. In reality, recession would be linked to the occurrence of storms, but this would be complex to allow for in a statistically meaningful manner, and hence constant rates are considered to be reasonable. This is common practice.

Given that the base beach profiles for hazard definition were dated in 2006, to project long term recession due to net sediment loss to the end of the design life at 2074 this is a period of 68 years. Accordingly, long term recession due to net sediment loss values at 2074 are as listed in Table L2.

Table L2: Adopted long term recession due to net sediment loss values at 2074

Scenario	Long term recession due to net sediment loss at 2074 (m)
95% exceedance ("mild case")	0
50% exceedance ("best" estimate)	3.4
5% exceedance ("severe case")	6.8

L3.3.5 Long Term Recession Due to Sea Level Rise

Based on Table AII.7.7 in IPCC (2013b), global mean sea level rises with respect to 1 January 2007 at 1 January 2074 for 4 representative concentration pathways (RCP) scenarios as well as the Special Report on Emissions Scenarios (SRES) A1B scenario used in the previous IPCC assessment (Meehl et al, 2007) are presented in Table L3. It is relevant to use 2007 as the starting year as base profiles for hazard definition were derived in 2006.

The projections were based on results from 21 Atmosphere-Ocean Global Circulation Models for each scenario, with 95% and 5% exceedances also shown (based on the range of model results). Assuming each scenario is equally likely, averages over all scenarios are also shown in Table L3. These averages were adopted as the global sea level rise values for use herein.

Table L3: Global mean sea level rise (m) from 2007 to 2074 from IPCC (2013b)

Emissions Scenario	Exceedance Probability		
	95% exceedance	Median	5% exceedance
SRES A1B	0.26	0.36	0.47
RCP2.6	0.20	0.30	0.39
RCP4.5	0.24	0.33	0.44
RCP6.0	0.24	0.33	0.43
RCP8.5	0.31	0.42	0.54
Average	0.25	0.35	0.45

Note that a key assumption in Table L3 is that the 95%, 5% and median exceedances of climate model results represent the corresponding probabilities of future sea level rise. This is considered to be reasonable until any information becomes available from the IPCC to enable an alternative assumption. It is recognised that if future anthropogenic greenhouse gas emissions are closer to any of the particular SRES or RCP scenarios, then averaging all scenarios becomes less relevant. That stated, the variability in model results between the various scenarios is considered to be relatively small.

It is also relevant to consider regional sea level rise variation, that is how the study area sea level rise may vary from the global mean. From Figure 13.21(a) of IPCC (2013b), although the resolution is coarse, it can be estimated that sea level rise in NSW is projected to be 10-20% larger than the global mean at 2081 to 2100. Assuming these increases also apply at 2074 relative to 2007, the following scenarios were adopted from the IPCC (2013b) information, as also summarised in Table L4:

- “mild case” estimate of 10% increase in sea level rise (0.02m) above 95% exceedance global mean in study area (that is, 0.27m sea level rise at 2074);
- “best” estimate of 15% increase in sea level rise (0.05m) above median global mean in study area (that is, 0.4m sea level rise at 2074); and
- “severe case” estimate of 20% increase in sea level rise (0.09m) above 5% exceedance global mean in study area (that is, 0.54m sea level rise at 2074).

Table L4: Adopted sea level rise at 2074 (relative to 2007)

Scenario	Global mean sea level rise from Table L3 (m)	Additional local sea level rise (m)	Adopted total sea level rise at 2074 (m)
95% exceedance (“mild case”)	0.25	0.02	0.27
50% exceedance (“best” estimate)	0.35	0.05	0.40
5% exceedance (“severe case”)	0.45	0.09	0.54

In Department of Environment, Climate Change and Water [DECCW] (2009a),there was also discussion on regional variation in sea level rise in the context of derivation of NSW sea level rise benchmarks at that time. DECCW (2009a) adopted increases in NSW sea level rise above the global mean of 0.1m at 2050 and 0.14m at 2100 based on upper limit projections.

From examination of the source of this information, namely McInnes et al (2007), it is evident that at 2070 the following projections were made of regional increases in NSW sea level rise above the global mean based on two different climate models (with no information provided as to which model could be considered most likely):

- “Low Mark 2”: 0 to 0.04m at both Wooli and Batemans Bay; and
- “High Mark 3” 0.08 to 0.12m at both Wooli and Batemans Bay.

These values are consistent with the IPCC (2013b) values adopted above. Woodroffe et al (2012) used a quadratic polynomial equation to define the variation in local sea level rise at Narrabeen relative to the global mean, and found that at 2074 (relative to 2007) the increase was 0.09m, as per the 5% exceedance value applied herein.

Linearly interpolating between the 2050 and 2100 sea level rise benchmarks in the former *NSW Sea Level Rise Policy Statement* (DECCW, 2009b)[14], which were relative to 1990, and adjusting to be relative to 2007, the equivalent sea level rise at 2074 from DECCW (2009b) is 0.59m. This is more severe than the 5% exceedance “severe case” value of 0.54m adopted herein. This emphasises that the former *NSW Sea Level Rise Policy Statement* sea level rise benchmarks were upper limit

[14] Which is no longer NSW Government policy.

projections. It is considered that the sea level rise probabilities and risk based framework applied herein is more appropriate than the direct adoption of the former sea level rise benchmarks[15].

Bruun (1962) proposed a methodology to estimate shoreline recession due to sea level rise, the so-called Bruun Rule. It can be described by the equation (Morang and Parson, 2002):

$$R = \frac{S \times B}{h + d_c} \tag{2}$$

where R is the recession (m), S is the long term sea level rise (m), h is the dune height above the initial mean sea level (m), d_c is the depth of closure of the profile relative to the initial mean sea level (m), and B is the cross-shore width of the active beach profile, that is the cross-shore distance from the initial dune height to the depth of closure (m). This equation is a mathematical expression that the recession due to sea level rise is equal to the sea level rise multiplied by the average inverse slope of the active beach profile (also see **Appendix I** and **Appendix J**).

For the investigation reported herein, long term recession calculations were completed using the Bruun Rule as outlined in Table L5 (Collaroy-Narrabeen Beach) and Table L6 (Fishermans Beach). The 50% exceedance average inverse slope of the active beach profile values were adopted based on an "inner Hallermeier" (Hallermeier, 1981, 1983) closure depth[16] at around 11m depth at Collaroy-Narrabeen Beach and 3m at Fishermans Beach. The 5% exceedance values were based on using the inner/outer nearshore sand boundary as a depth of closure at around 17m depth at Collaroy-Narrabeen Beach and 5m depth at Fishermans Beach . The 95% exceedance values were based on using the inverse slope of the subaerial beach face (swash area) based on review of photogrammetric data.

Table L5: Long term recession due to sea level rise calculations for Collaroy-Narrabeen Beach

Scenario	Average inverse slope of active beach profile	Sea level rise at 2074 from Table L4	Long term recession due to sea level rise at 2074 (m) from Equation 2
95% exceedance ("mild case")	13	0.27	3.6
50% exceedance ("best" estimate)	30	0.40	12.0
5% exceedance ("severe case")	40	0.54	21.6

Table L6: Long term recession due to sea level rise calculations for Fishermans Beach

Scenario	Average inverse slope of active beach profile	Sea level rise at 2074 from Table L4	Long term recession due to sea level rise at 2074 (m) from Equation 2
95% exceedance ("mild case")	11	0.27	3.0
50% exceedance ("best" estimate)	20	0.40	8.0
5% exceedance ("severe case")	30	0.54	16.3

Ranasinghe et al (2012), updating Ranasinghe et al (2009), has developed an alternative method to the Bruun Rule, using a process based model of dune erosion and recovery to derive probabilistic

[15] Also note that the sea level rise values derived herein were based on the latest 5th IPCC assessment (IPCC, 2013a, b), whereas the DECCW (2009b) benchmarks were derived from the previous 4th IPCC assessment (Meehl et al, 2007).
[16] See **Appendix I** and **Appendix J** for further discussion.

estimates of sea level rise driven coastal recession. Applying the so-called Probabilistic Coastline Recession (PCR) model at a profile near Narrabeen Street at Narrabeen Beach, they estimated long term recession due to sea level rise at 2100 for exceedance probabilities varying between 1% and 100%.

Ranasinghe et al (2012) used a sea level rise value of 0.92m in their modelling, and a comparison of their results with those derived using the same parameters used herein (but again using the 0.92m sea level rise value) are outlined in Table L7. It is evident that the results are generally similar, with the methodology adopted herein more conservative at the 50% exceedance level. That stated, the approach herein differs to Ranasinghe et al (2012) in that different sea level values were used for different exceedance scenarios, which is considered to be more appropriate given the uncertainty in future sea level rise. Ranasinghe et al (2012) considered that Bruun Rule estimates were far larger than using their PCR model, but Table L7 indicates that by applying the depths of closure adopted herein, the Bruun Rule and PCR results are similar.

Table L7: Comparison of Ranasinghe et al (2012) long term recession due to sea level rise estimates at 2100 with those using parameters herein for 0.92m sea level rise (at Narrabeen Beach)

Scenario	Ranasinghe et al (2012) long term recession due to sea level rise at 2100	Equivalent long term recession due to sea level rise at 2100 using parameters herein (m)
95% exceedance	14.9	12.0
50% exceedance	21.9	27.6
5% exceedance	36.9	36.8

The values in Table L5 and Table L6 were adopted as long term recession due to sea level rise estimates for use herein.

L3.3.6 Adjustment for Beach Rotation Inherent in 2006 Base Profiles

In WorleyParsons (2009), the year 2006 base profile for hazard definition was adjusted at Collaroy-Narrabeen Beach (only) to take account of the fact that at this date the beach face was rotated relatively anti-clockwise (relatively eroded in the north and accreted in the south). This adjustment moved the hazard lines at the northern end of Collaroy-Narrabeen Beach further seaward, and moved the hazard lines at the southern end of Collaroy-Narrabeen Beach further landward, to better correspond to calculations for “average beach full” base profiles (also see **Appendix I**).

This adjustment was also applied herein at all Collaroy-Narrabeen Beach profiles.

L3.3.7 Future Beach Rotation and Uncertainty Allowance

Three scenarios were considered and applied at Collaroy-Narrabeen Beach to account for future rotation and uncertainty over the design life (in addition to the adjustment described in Section L3.3.6), namely:

- a “mild case” estimate (95% probability of exceedance) of zero additional translation;
- a “best” estimate (50% probability of exceedance) of 5m additional landward translation; and

- a "severe case" estimate (5% probability of exceedance) of 20m additional landward translation.

As described in Section 2.5 of the main report, there is about a 20m to 30m distance between the mean and most accreted or eroded shorelines at Collaroy-Narrabeen Beach, based on monthly measurements since 1976[17]. For the "severe case" above, it was thus being assumed that the design storm would be occurring near to the most eroded position. This is conservative for two reasons:

- beach rotation does not lead to additional landward recession over the entire beach, but one end of the beach prograding and the other receding; and
- the full design storm demand is unlikely to be realised near an eroded profile as the existence of offshore bars would be expected to limit erosion.

The "mild case" could actually have been adopted as a seaward translation, but was set as zero to be conservative and to take account of uncertainty. The 5m landward translation for the "best estimate" is also likely to be conservative, but is considered to be reasonable given uncertainty in future changes to storminess and wave directions.

There is no significant evidence of beach rotation at Fishermans Beach in the historical record, and the relatively sheltered nature of the beach makes an additional allowance for uncertainty less relevant. Therefore, the allowances for future beach rotation and uncertainty applied at Collaroy-Narrabeen Beach as described above were not applied at Fishermans Beach.

L3.3.8 Combined Effects

The combination of long term recession due to net sediment loss (Section L3.3.4), long term recession due to sea level rise (Section L3.3.5) and beach rotation (Section L3.3.7) gives the total landward translations listed in Table L8.

Table L8: Adopted landward translations to define recession and rotation effects at 2074

Scenario	Recession and Rotation Allowance at 2074 (m)	
	Collaroy-Narrabeen	Fishermans Beach
95% exceedance ("mild case")	3.6	3.0
50% exceedance ("best" estimate)	20.4	11.4
5% exceedance ("severe case")	48.4	23.1

The translations were included after the storm demand was applied as discussed in Section L3.3.2, and adjustment to the 2006 profiles at Collaroy-Narrabeen Beach was made for beach rotation as discussed in Section L3.3.6. It is recognised that this approach is simplistic as it assumes that the storm erosion and recession occur instantaneously, whereas in reality recession would occur first (with some uncertainty as the how the dune morphology may change over time, for example whether it would 'roll back' the dune or cut into it[18]) and then the storm demand volume would be removed from profiles different to those in 2006.

[17] This is not due to rotation alone, but also cross-shore beach erosion and accretion cycles.
[18] In addition, sea level rise would be expected to cause the dune crest to rise in elevation in response as it translates landwards.

Kinsela and Hanslow (2013) have discussed this issue, noting that “it may not be conservative to expect that the development of coastal morphology will maintain pace with projected rapidly accelerating sea level rise”. However, areas landward of the dune crest in the study area are generally at similar elevations (that is, the areas landward of the dune crest are generally relatively flat), and recession would be constrained while protective works are in place (as applies at the southern end of Collaroy-Narrabeen Beach). Therefore, the issue is likely to be relatively insignificant in the study area and has not been allowed for herein. That stated, this issue could be considered in future revisions of the CZMP if further information becomes available on potential dune responses to sea level rise.

L4. CONSEQUENCES (IGNORING EXISTING PROTECTIVE WORKS AND NON-SANDY SUBSURFACES)

AGS (2007a, b) used 5 consequence descriptors. These descriptors were related to the percentage of damage caused to a property due to a landslide event, relative to the market value of the property (land plus structures), as listed in Table L9.

Table L9: Consequence descriptors from AGS (2007a, b)

Descriptor	Approximate cost of damage	Description
Catastrophic	> 100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.
Major	40% to 100%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.
Medium	10% to 40%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage
Minor	1% to 10%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works
Insignificant	< 1%	Little damage

For the investigation reported herein, it was considered that the appropriate consequence descriptor for storm erosion leading to a slumped erosion escarpment immediately seaward of a structure on conventional foundations[19] (such as strip footings or shallow piers) was "minor". Although a structure immediately landward of a slumped escarpment may not be damaged at all, in recognition of the structure being in a Zone of Reduced Foundation Capacity (Nielsen et al, 1992)[20] and hence having a lower factor of safety, it was considered that there was the potential for some damage.

For development on appropriately engineered piled foundations, it was considered that the appropriate consequence descriptor for structures immediately landward of the slumped erosion escarpment was "insignificant". Indeed, a structure could be well seaward of the slumped erosion escarpment and be designed with piled foundations to not be damaged for a suitably low probability event (structures can be designed to be at acceptable risk in the ocean itself).

Given that hazard lines are defined herein at the landward edge of the Zone of Slope Adjustment, if used as setback lines for development this is thus equivalent to setting the consequences at that line as "minor" for development on conventional foundations and "insignificant" for development on piled foundations.

AGS (2007a, b) defines the approximate cost of damage (as per Table L9) to include:

- the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the erosion which has occurred and professional design fees; and
- consequential costs such as legal fees and temporary accommodation.

[19] Note that some practitioners distinguish "foundations" from "footings", with the latter being the structural element (such as a pier) and the former being the ground material that this structural element bears upon. However, to be consistent with Nielsen et al (1992), the term "foundations" is used herein to refer to the structural element.

[20] Also see **Appendix I**.

It is recognised that the land seaward of a structure sited landward of a particular setback line (for example, backyards of beachfront development) may be eroded in coastal storms, and that this does have consequences on the use of that land and landowner beach access, and may damage minor structures such as fences, decks, clothes lines and the like. This loss of land may also affect land values (a consequential loss) and have some reinstatement costs[21].

However, given that the focus of the investigation reported herein was on defining acceptable risk for structures approved as part of the development assessment process, it was considered most appropriate to only consider risk to those structures that would be considered as part of a development application to Council, for which consequential losses are likely to be minimal given limited damage to the approved structures. Any loss of land amenity was assumed to be mitigated by natural recovery and through adoption of the measures discussed in Section L10.2.4.

Some specific sites may require additional consideration due to other consequences not considered herein, such as removal of property access via public roads.

In adopting the consequences descriptors of "minor" for development on conventional foundations and "insignificant" for development on piled foundations, it is assumed that there are no additional coastal hazards landward of the slumped erosion escarpment. Such hazards could include wave runup and overtopping forces on structures, or inundation of floor areas, that lead to damage. It is recognised that these hazards would need to be managed as part of defining acceptable risk to development, for example through ensuring ground floor levels are at least 0.5m above adjacent ground levels and appropriate regard has been made for these effects in the design. It is recommended that applicants in the study area be required to obtain coastal engineering advice to address issues of acceptable risk to new development from inundation in relation to design and construction.

[21] However, it should be recognised that coastal land "naturally" recovers after storm events, with sand that had moved offshore in the storm returning to build the beach back up under calmer conditions after the storm. That is, any loss of land values may be temporary, and reinstatement costs may not be significant if the landowner can wait for natural recovery.

L5. ACCEPTABLE RISK (IGNORING EXISTING PROTECTIVE WORKS AND NON-SANDY SUBSURFACES)

A risk matrix is presented in AGS (2007a, b), as shown in Figure L2. For example, if the consequences of a particular "unlikely" event were "minor", then the risk would be considered "low".

Figure L2: AGS (2007a, b) risk matrix

Likelihood	Consequence				
	Catastrophic	**Major**	**Medium**	**Minor**	**Insignificant**
Almost Certain	Very High	Very High	Very High	High	Medium
Likely	Very High	Very High	High	Medium	Low
Possible	Very High	High	Medium	Medium	Very Low
Unlikely	High	Medium	Low	Low	Very Low
Rare	Medium	Low	Low	Very Low	Very Low
Barely Credible	Low	Very Low	Very Low	Very Low	Very Low

AGS (2007a, b) defined "acceptable risk" as follows:

> "A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable".

A key aspect of the AGS (2007a, b) approach is that they defined the acceptable level of risk for new development as being "low" risk (or lesser, that is "very low") as per the matrix in Figure L2. This was based on review of the limited literature available, extensive discussion amongst the AGS Working Group, and consideration of the annualised cost of damage to property. AGS (2007a, b) concluded that:

> "most informed home owners are likely to be risk averse as a result of appreciation of the consequences at a family or personal level, almost regardless of the likelihood of the event. This risk aversion suggests that Low Risk to Property is an appropriate recommendation for acceptable risk to the regulator for domestic dwellings which are of Importance Level 2 (as defined in the BCA [Building Code of Australia])".

Note that AGS (2007a, b) considered that the acceptable risk level was "low" for structures of both:

- Importance Level 2 (such as low-rise residential construction)[22]; and
- Importance Level 3 (such as buildings and facilities where more than 300 people can congregate in one area, schools of greater than 250 people, health care facilities with a capacity of 50 or more residents, power generating facilities, water treatment and waste water treatment facilities).

For structures of Importance Level 4 (such as buildings and facilities designated as essential facilities or with special post-disaster functions, medical emergency or surgery facilities, emergency service facilities (fire, rescue, police etc.), the designated acceptable risk level was "very low". The only

[22] For structures of Importance Level 1 (such as minor temporary facilities), the designated acceptable risk level was "medium".

known structure of Importance Level 4 in the study area is Narrabeen Fire Station at 9 Ocean Street Narrabeen (located immediately south-west of the Marquesas development). Additional assessment would be require to define acceptable risk lines for this site, but it is noted that the site is relatively landward.

Given that "low" risk can be considered acceptable for typical structures in the study area, it follows from Figure L2 that:

- the "unlikely" likelihood line can define the acceptable risk setback for new development that is constructed on conventional foundations (since, as noted in Section L4, this has "minor" consequences); and
- the "likely" likelihood line can define the acceptable risk setback for new development that is constructed on piled foundations (since, as noted in Section L4, this has "insignificant" consequences).

L6. DELINEATION OF LIKELIHOOD LINES IN STUDY AREA (IGNORING EXISTING PROTECTIVE WORKS AND NON-SANDY SUBSURFACES)

L6.1 Procedures Considered

Two procedures were applied to define likelihood lines ("almost certain", "likely", "possible", "unlikely" and "rare" as per Table L1) in the study area, namely:

- Type 1: a storm event occurring at any time over the design life, ignoring recession[23]; and
- Type 2: a storm event occurring in the last year of the design life, after the full magnitude of recession as per Table L8 had been realised.

The storm event probabilities are different in these procedures. For Type 1, the event can occur at any time over the design life, so for example a 0.5% AEP (200 year ARI) event has a 26% probability over the design life in Type 1 for a 60 year life. However, a 0.5% AEP event is treated as 0.5% probability for Type 2, which when multiplied by the recession scenario probability (for example 50% for the "best" estimate) gives the probability over the design life (0.25% in this example).

That is, once recession is included, the probability of the event occurring in the last year (only) of the design life is considered (as per Type 2), and the event probability is much lower than the probability of occurring at any time during the design life (as per Type 1).

As noted in Section L3.3.2, likelihood lines were defined at the landward edge of the Zone of Slope Adjustment, with the storm demand volume (Section L3.3.1) applied to 2006 profiles. At Collaroy-Narrabeen Beach, adjustment for 2006 rotation was undertaken (Section L3.3.6).

It was found that the "almost certain", "likely" and "possible" likelihood landward limits were most appropriately defined using the Type 1 procedure, as this gave the most landward and physically realistic hazard lines. The "unlikely" and "rare" likelihood[24] landward limits were most appropriately defined using the Type 2 procedure, in part because using the Type 1 procedure in this case would lead to relatively large extrapolation of Figure L1, reducing confidence[25].

The calculation methodologies for the Type 1 and Type 2 procedures are described in Section L6.2 and Section L6.3 respectively.

It is recognised that more advanced statistical approaches and Monte Carlo modelling could be undertaken to refine the estimates provided herein. It is recommended that these approaches are considered in the future as understanding develops of the appropriate probability distributions to adopt in these analyses.

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[23] Recession was not included in the Type 1 procedure adopted herein. It was assumed that the design event occurred at any time over the design life, but the recession component was not included. In reality, the design storm can occur at any time over the design life, and the recession depends on the year of the event. For example, a 0.5% AEP event could occur in say Year 1, or Year 20, or Year 60, and the probability of that event occurring is 0.5% in each case. However, the recession component would vary in each case. As a future refinement to this investigation, it may be possible to model the bivariate distribution of the joint probability of the storm erosion and recession to consider both processes in a Monte-Carlo modelling exercise.
[24] Note that the "barely credible" likelihood is represented by the area landward of the "rare" likelihood line.
[25] That stated, similar results to Type 2 were obtained using the Type 1 procedure to define "unlikely" and "rare" likelihoods.

L6.2 Storm Event Occurring any Time Over Design Life, Ignoring Recession (Type 1)

Based on the relationships between likelihood and AEP from Table L1, the conversion from AEP to ARI as follows[26]:

$$ARI = \frac{-1}{ln(1-AEP)} \tag{3}$$

and the relationships between ARI and storm demand from Figure L1, storm erosion volumes for the "almost certain", "likely", and "possible" likelihoods were determined as shown in Table L10.

Table L10: Storm demands at Collaroy-Narrabeen Beach and Fishermans Beach corresponding to "almost certain", "likely", and "possible" likelihoods for Type 1 procedure

Likelihood	Cumulative probability over design life (%)	AEP (%)	ARI (years)	Storm demand (m^3/m)	
				Collaroy-Narrabeen	Fishermans
Almost Certain	95.4%	5	19.5	175	70
Likely	26%	0.5	199	280	113
Possible	3%	0.05	1,999	390	155

These respective storm demand volumes were applied at Collaroy-Narrabeen Beach and Fishermans Beach as per Section L3.3.1 and L3.3.2, along with allowance for 2006 rotation as per Section L3.3.6 (at Collaroy-Narrabeen Beach only). This defined the landward edge of the Zone of Slope Adjustment, which in turn defined the likelihood line for the three likelihoods considered.

L6.3 Storm Event Occurring in Last Year of Design life, With Recession (Type 2)

The "unlikely" and "rare" likelihood landward limits were defined using the Type 2 procedure. The procedure adopted herein has been to consider the probability of a particular storm erosion volume occurring in the last year of the design life (after long term recession has been realised). This is appropriate as it equally likely that a particular storm of probability *P* occurs in 2014 or 2074 (ignoring any potential increases in the severity or frequency of storms under climate change), and the later a storm of probability *P* occurs in the design life the further landward it would extend due to greater prior recession.

The first step in this procedure was to define the storm event probability (AEP) for a storm occurring in the last year of the design life after recession had occurred. This required the storm event AEP (probability), when multiplied by the relevant probability for the scenario (for example, 50% for the 50% exceedance "best" estimate scenario), being equal to the cumulative probability over the design life associated with the particular likelihood (see Table L11).

For example, for the "unlikely" likelihood, the required cumulative probability over the design life is 0.3%. For the 50% exceedance ("best" estimate) scenario, the storm demand event AEP is 0.6% ($0.006 \times 0.5 \times 100 = 0.3\%$).

[26] Where ARI is in years, and AEP is expressed as a decimal (for example, 6.6% becomes 0.066).

In multiplying the probabilities together it was assumed that the storm event and recession scenarios are independent. These processes are not completely independent, as coastal storms are mostly driven by weather patterns leading to large waves and elevated water levels, while recession would mostly be driven by sea level rise, and water level is a factor in both. However, assuming independence is considered to be a conservative approach.

Table L11: Storm event probabilities that would achieve particular likelihood probabilities for the three exceedance scenarios considered

Likelihood	Cumulative probability of event occurring over design life	Storm demand event AEP (%)		
		95% exceedance	50% exceedance	5% exceedance
Unlikely	0.3%	0.3	0.6	6.0
Rare	0.03%	0.03	0.06	0.60

In Table L12, the storm event probabilities in Table L11 were converted to ARI's using Equation 3:

Table L12: Storm event ARIs corresponding to events in Table L11

Likelihood	Cumulative probability of event occurring over design life	Storm demand event ARI (years)		
		95% exceedance	50% exceedance	5% exceedance
Unlikely	0.3%	320	170	16
Rare	0.03%	3170	1670	170

Based on Figure L1, the storm demand volumes corresponding to these events were determined as shown in Table L13 (Collaroy-Narrabeen Beach) and Table L14 (Fishermans Beach).

Table L13: Storm demand volumes for Collaroy-Narrabeen Beach corresponding to events in Table L12

Likelihood	Cumulative probability of event occurring over design life	Storm demand volume (m^3/m)		
		95% exceedance	50% exceedance	5% exceedance
Unlikely	0.3%	300	270	170
Rare	0.03%	410	380	270

Table L14: Storm demand volumes for Fishermans Beach corresponding to events in Table L12

Likelihood	Cumulative probability of event occurring over design life	Storm demand volume (m^3/m)		
		95% exceedance	50% exceedance	5% exceedance
Unlikely	0.3%	120	110	70
Rare	0.03%	160	150	110

These respective storm demand volumes were applied at Collaroy-Narrabeen Beach and Fishermans Beach as per Section L3.3.1 and L3.3.2., along with allowance for 2006 rotation as per Section L3.3.6 (at Collaroy-Narrabeen Beach only). This defined the landward edge of the Zone of Slope Adjustment. The setback for the particular scenario (95%, 50% or 5% exceedance) was then applied as per Table L8, to define the likelihood lines for the two likelihoods considered.

The critical events (that produced the most landward setback) for each likelihood are highlighted in red in Table L13 and Table L14, namely the 5% exceedance ("severe case") scenarios.

L6.4 Summary of Parameters Defining Each Likelihood Line

A summary of the adopted storm demand and long term recession parameters to define each likelihood line is provided in Table L15 for Collaroy-Narrabeen Beach, and Table L16 for Fishermans Beach.

Table L15: Parameters defining lines of various likelihood at Collaroy-Narrabeen Beach

Likelihood	Storm Demand (m^3/m)	Recession allowance (m)
Almost Certain	175	Nil
Likely	280	Nil
Possible	390	Nil
Unlikely	170	48.4
Rare	270	48.4

Table L16: Parameters defining lines of various likelihood at Fishermans Beach

Likelihood	Storm Demand (m^3/m)	Recession allowance (m)
Almost Certain	70	Nil
Likely	113	Nil
Possible	155	Nil
Unlikely	70	23.1
Rare	110	23.1

L6.5 Plots of Likelihood Lines in Study Area, and Comparison to Traditional Hazard Lines

Plots of the "almost certain", "likely", "possible", "unlikely" and "rare" likelihood lines are provided (moving north to south along the study area) in Figure L3 to Figure L7. Traditional Immediate, 2050 and 2100 coastline hazard lines (defined at the landward edge of the Zone of Slope Adjustment [ZSA]) are also depicted for comparison (see **Appendix I** for discussion on how the traditional lines were developed). The seaward edge of known protective works is also shown, which cover most of the length of Collaroy-Narrabeen Beach south of Devitt Street.

It is evident that the "likely" likelihood line is similar to the traditional Immediate ZSA, while the "possible" likelihood line is similar to the traditional 2050 ZSA along the northern portion of Collaroy-Narrabeen Beach and at Fishermans Beach (the 2050 ZSA is seaward of the "possible" line in the southern portion of Collaroy-Narrabeen Beach). The 2100 ZSA is generally located between the "unlikely" and "rare" likelihood lines.

Therefore, adopting the “unlikely” likelihood line as the acceptable risk setback for new development on conventional foundations is similar to adopting the 2100 ZSA, which (it turns out) is consistent with traditional coastal engineering practice. Adopting the “likely” likelihood line as the acceptable risk setback for new development constructed on piled foundations is similar to adopting the Immediate ZSA, which (it turns out) is consistent with historical coastal management practice in Warringah.

Figure L3: Adopted likelihood lines (ignoring existing protective works and non-sandy subsurfaces) at northern end of Narrabeen Beach

Figure L4: Adopted likelihood lines (ignoring existing protective works and non-sandy subsurfaces) near Narrabeen Street to Albemarle Street at southern end of Narrabeen Beach

Figure L5: Adopted likelihood lines (ignoring existing protective works and non-sandy subsurfaces) from Stuart Street to Robertson Street at Collaroy-Narrabeen Beach

Figure L6: Adopted likelihood lines (ignoring existing protective works and non-sandy subsurfaces) at southern end of Collaroy Beach

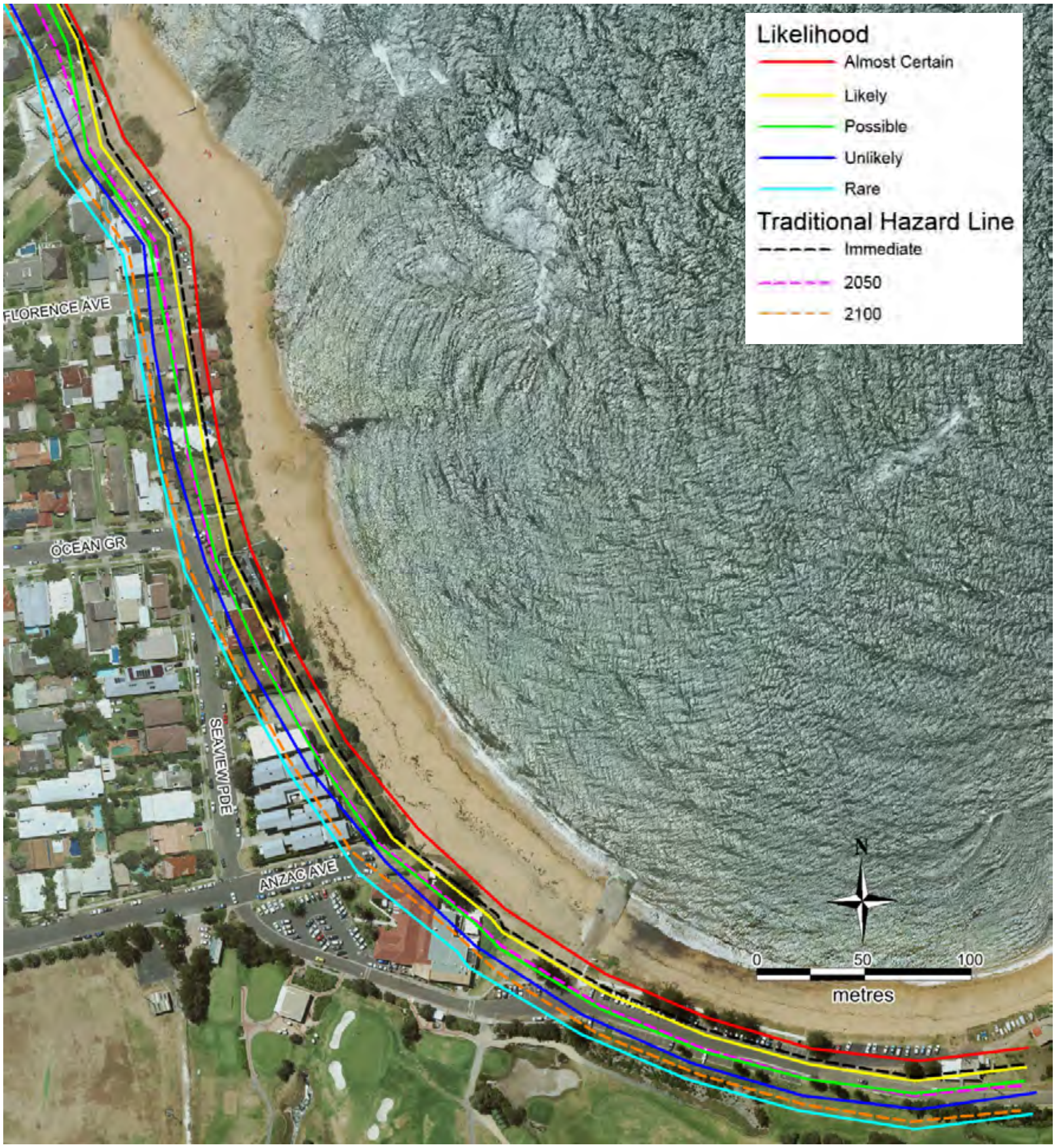

Figure L7: Adopted likelihood lines (ignoring existing protective works and non-sandy subsurfaces) at Fishermans Beach

L7. CONSIDERATION OF EXISTING PROTECTIVE WORKS

While the existing protective works at the southern end of Collaroy-Narrabeen Beach remain in place, erosion and recession would be constrained from progressing landward of the works. Indeed, the works have successfully provided property protection over the last 40 or so years.

However, the protective works are variable in standard, and they may be undersized and/or founded inadequately. Most of the works are not engineer designed nor approved structures, and were generally implemented by various landowners and authorities and constructed from the 1920's onwards, and mostly in the 1960's and 1970's during or immediately after erosion events. Also, full details of the protective works are generally unknown or uncertain.

Given this, as well as the potential for larger waves attacking the structures under sea level rise[27] (and more frequent wave attack as the beach width narrows due to shoreline recession associated with sea level rise), future effectiveness of the protective works cannot be guaranteed.

To define acceptable risk to new development in areas with known protective works, it is considered that the critical case is complete failure of the works in a storm event, which can occur at any time over the design life. There is no need for recession to be considered in this case, as recession landward of the works cannot occur until failure.

The ("unlikely") acceptable risk with conventional foundations for this scenario can be approximated by the storm event that has a 0.3% probability of occurring during the design life. Following the methodology outlined in Section L6.2, the ARI of this 0.005% AEP (see Table L1) event is 20,000 years, with a storm demand of 495m^3/m (reducing south of Frazer Street) based on a linear extrapolation of Figure L1. The line so defined with this storm demand is very similar to the "unlikely" line defined in Section L6.5.

Rock revetments can fail if undermined (leading to collapse of the structure), overtopped (leading to sand removed from behind and again potential collapse) and/or the rocks become mobile due to insufficient mass. Examples of failed revetments are provided in Figure L8 and Figure L9.

However, at Collaroy-Narrabeen Beach, failed protective works (particularly the rock revetments) would most likely limit some of the storm demand due to the significant spatial extent of the works. Even if undermined and/or rocks were dislodged, the revetments would be expected to limit erosion in the lower profile. Therefore, it is considered a reasonable assumption that any failed protective works (rock revetments) would most likely (conservatively) reduce 10% to 20% of the storm demand (that is, 80% to 90% of the theoretical storm demand could be realised). This would essentially shift the "conventional foundations" acceptable risk line (in areas with existing protective works) from the "unlikely" line to the "possible" line[28]. For piled development, this would essentially shift the acceptable risk line (in areas with existing protective works) from the "likely" line to the traditional Immediate Hazard line[29].

[27] Note that the required rock mass in rock revetment structures (which are the most common protective works at Collaroy-Narrabeen Beach) is proportional to the wave height cubed, so a small increase in wave height can lead to a large increase in the required mass, meaning that existing structures are more likely to become unstable in the future.

[28] The "possible" line was defined by a storm demand of 390m^3/m in the most exposed areas of Collaroy-Narrabeen Beach. This is about 80% of 495m^3/m.

[29] The "likely" and Immediate Hazard lines were defined by storm demands of 280m^3/m and 250m^3/m respectively in the most exposed areas of Collaroy-Narrabeen Beach. The latter is about 89% of the former.

Figure L8: Erosion landward of revetment at Stockton Beach in July 1999

Figure L9: Erosion landward of revetment at Wamberal Beach in June 1978

L8. CONSIDERATION OF NON-SANDY SUBSURFACES

At Fishermans Beach, it is known that there are rock and stiff clays present in the theoretical active erosion/recession zone. It would be expected that these non-sandy subsurface materials would limit the full realisation of typical sandy beach coastline hazards at Fishermans Beach.

However, given the spatial variability in subsurface conditions and limited spatial density of boreholes that have been drilled to assess the nature of the subsurface, it is not currently possible to definitively make an allowance for any reduced erosion and recession at Fishermans Beach to define acceptable risk setbacks.

Therefore, acceptable risk lines were determined at Fishermans Beach necessarily assuming an entirely sandy subsurface. Discussion on the practical application of this approach is provided in Section L10.2.3.

L9. PLOTS OF ACCEPTABLE RISK LINES DETERMINED IN STUDY AREA

As described in Section L5, in areas with no known protective works:

- the "unlikely" likelihood line is the acceptable risk setback for new development on conventional foundations; and
- the "likely" likelihood line is the acceptable risk setback for new development constructed on piled foundations.

As noted in Section L7, in areas with known protective works:

- the "possible" likelihood line is the acceptable risk setback for new development on conventional foundations; and
- the Immediate ZSA Hazard Line is the acceptable risk setback for new development constructed on piled foundations.

Plots of the acceptable risk lines to define the setback for new development on conventional foundations and on piled foundations in the study area are provided in Figure L10 to Figure L14. Lot boundaries of private development are also shown. It is proposed that future development would be landward of these lines as relevant to the foundation type, and potentially further landward based on amenity and other considerations as discussed in Section L10.2.

Figure L10: Acceptable risk setback lines determined at northern end of Narrabeen Beach

Figure L11: Acceptable risk setback lines determined near Narrabeen Street to Albemarle Street at southern end of Narrabeen Beach

Figure L12: Acceptable risk setback lines determined from Stuart Street to Robertson Street at Collaroy-Narrabeen Beach (including consideration of existing protective works)

Figure L13: Acceptable risk setback lines determined at southern end of Collaroy Beach (including consideration of existing protective works)

Figure L14: Acceptable risk setback lines determined at Fishermans Beach

L10. IMPLICATIONS FOR DEVELOPMENT CONTROLS

L10.1 Observations from Figures in Section L9

The following observations can be made for any new private development proposed north of Devitt Street (Figure L10, Figure L11, and part Figure L12):

- new development, if on piled foundations, would be at acceptable risk at all lots;
- if the seaward face of new development was to remain at the position of the seaward face of existing development, most new development would need to be piled; and
- in this area, particularly north of Wellington Street, there would be opportunities to move new development further landward than existing at many lots (due to the relatively large cross-shore lot size), and to therefore be at acceptable risk on conventional foundations rather than adopting piling.

For new private development south of Devitt Street at Collaroy-Narrabeen Beach, where there are extensive existing protective works (part Figure L12, and Figure L13):

- new development, if on piled foundations, would be acceptable at all lots north of Wetherill Street;
- the seaward face of new development would need to be further landward than the seaward face of existing development at some of these lots;
- new development, even if on piled foundations, would be severely restricted (in terms of available lot area) between Wetherill Street and Stuart Street;
- private development (even if piled) would not be feasible south of Stuart Street; and
- north of Mactier Street, there would be opportunities to move new development further landward than existing at many lots (due to the relatively large cross-shore lot size), and to therefore be at acceptable risk on conventional foundations rather than adopting piling.

For new private development at Fishermans Beach (Figure L14), in the absence of any geological/geotechnical constraints, that is assuming an entirely sandy subsurface:

- new development, if on piled foundations, would be acceptable at all lots except at the lot immediately south of Florence Avenue (9 Florence Avenue)[30];
- new development would need to be further landward than existing at the 2 lots north of Ocean Grove (1 and 3 Ocean Grove); and
- most development would need to be piled if built to the same seaward extent.

The following observations can be made on public structures:

- all surf clubs (North Narrabeen, Narrabeen, South Narrabeen and Collaroy) would need to be piled if redeveloped with the same seaward extent as existing;
- the seaward portion of the Long Reef Golf Club clubhouse would need to be piled if redeveloped with the same seaward extent as existing[31]; and
- the Warringah Surf Rescue building and Long Reef Fishing Club Hut would need to be relocated if redeveloped[31].

[30] New development would also be severely restricted (in terms of available lot area) at the lot south of Ocean Grove (11 Seaview Parade).
[31] In the absence of any geological/geotechnical controls, that is assuming an entirely sandy subsurface.

L10.2 Practical Application

L10.2.1 Narrabeen Beach north of Devitt Street

For the area north of Devitt Street, there can be relatively straightforward application of the two acceptable risk setback lines to define the location of new development (on conventional or piled foundations), without any significant negative impacts on landowners or public beach amenity. A fixed 6m rear (seaward boundary) building setback (as per the *Warringah Development Control Plan*) could be applied at most lots to achieve a consistent seaward building alignment, with the only exception being immediately south of Loftus Street (at 2 Loftus Street Narrabeen).

However, most development is currently setback over 10m from the rear (seaward) boundary, and it is recommended that there is consideration of adopting a future setback consistent with this current building alignment to ensure that the most seaward development generally moves no further seaward. This would ensure that impacts on views and privacy from neighbouring development, and impacts on beach amenity from structures imposing on the beach outlook, would be minimised.

A 15m setback from the seaward property boundary is considered to be generally consistent with current building alignments north of Devitt Street at Collaroy-Narrabeen Beach, as shown in Figure L15[32] and Figure L16 in relation to the acceptable risk lines. If the 15m setback was adopted as the minimum setback for piled development, of the 44 beachfront lots in this area:

- most new development could be positioned with the same seaward extent as existing (at 28 lots or 64%);
- some new development could move seaward (at 10 lots or 23%);
- some new development would be required to move landward, but still enabling feasible development at the lot (at 4 lots or 9%);
- development would not be feasible at 2 Loftus Street Narrabeen (the beachfront lot immediately south of Loftus Street); and
- one lot is currently vacant.

Site specific controls relating to property access would also be required as discussed in Section L10.2.4. 2 Loftus Street Narrabeen is discussed further in that Section, but it can be noted here that if access was piled as outlined there, there may be consideration of not applying the 15m setback at that lot given that such a setback would be impractical for a lot of that shape, and development could still be at acceptable risk.

[32] Note that the 15m setback was extrapolated at the northern end of this Figure. Also, the acceptable risk line for conventional foundations was slightly smoothed compared to Figure L10 to remove kinks that would be unlikely to be sustained in practice.

Figure L15: 15m setback and acceptable risk setback lines at northern end of Narrabeen Beach

Figure L16: 15m setback and acceptable risk setback lines near Narrabeen Street to Albemarle Street at southern end of Narrabeen Beach

L10.2.2 Collaroy-Narrabeen Beach south of Devitt Street

For the area south of Devitt Street at Collaroy-Narrabeen Beach, there would have to be the introduction of an additional control to enable development at acceptable risk to be maintained at many lots, namely upgrading of existing protective works. This upgrading would require current coastal engineering design standards to be adopted for a design life of at least 60 years, and the protective works being certified as having been constructed to this design.

Upgrading of the existing protective works at a lot would enable a landowner to construct seaward of the acceptable risk line for piled development. A CZMP action in Section 11 of the main report is to develop design requirements for upgraded/new protective works (including alignment and minimum setback for new development located landward of the upgraded/new protective works).

For the purposes of the CZMP a minimum setback for piled development with upgraded/new protective works has been defined based on a 15m setback from the seaward lot boundary (as per north of Devitt Street, see Section L10.2.1)[33]. These setbacks are depicted in Figure L17 and Figure L18 in relation to the acceptable risk lines. The reason why such a setback is necessary is to prevent development moving so far seaward with construction of protective works so as to impact on:

- equity (for example, view loss for neighbours due to existing building lines);
- beach amenity (for example, visual impact of structures near the public beach);
- available space for construction of protective works on private land; and
- protective works maintenance (allowing space for plant and equipment to work seaward of development to undertake maintenance on the protective works if required).

It should be recognised that setbacks in the order of 10m to 20m may not provide enough available space for construction of conventional rock revetments (at 1:2 slope), while also allowing access for maintenance. Accordingly, it may be necessary for hybrid revetments (that is, with a vertical seawall toe and upper sloping rock revetment) or vertical seawalls to be constructed, to reduce the footprint of the protective works.

If the 10m, 15m or 20m setback (as applicable) was adopted as the minimum setback for piled development with upgraded/new protective works, of the 49 beachfront lots in this area:

- 27% of new development could be positioned with the same seaward extent as existing (at 13 lots);
- 45% of new development could move seaward (at 22 lots);
- 27% of new development would be required to move landward, but still enabling feasible development at the lot (at 13 lots); and
- development would not be feasible at Collaroy Services Beach Club.

There may be consideration of allowing new development at Collaroy Services Beach Club over the existing footprint (if it was piled and upgraded/new protective works were constructed) as an exception, given that there is no adjacent alongshore development and the land has been developed since the 1920's.

[33] With the exception of a 20m setback between Wetherill Street and Stuart Street (as the lot boundary is relatively seaward of the sand/vegetation interface in this area and most existing development is set back further than 20m in this area) and the exception of a 10m setback between Stuart Street and Ramsay Street (as the lot boundary is relatively landward of the sand/vegetation interface in this area).

Figure L17: 15m setback (20m from Stuart to Wetherill Street) and acceptable risk lines from Stuart Street to Robertson Street at Collaroy-Narrabeen Beach

Figure L18: 15m setback (10m from Ramsay to Stuart Street) and acceptable risk lines at southern end of Collaroy Beach

For new development to remain at the existing seaward extent, it would be necessary for protective works to be upgraded at most lots in this area. For new development to be at acceptable risk south of Stuart Street, it would be necessary for the existing protective works to be upgraded at all lots (and development would be severely restricted between Wetherill Street and Stuart Street without upgrading of protective works).

Between Stuart Street and Ramsay Street, where there are no known existing protective works, it is likely to be necessary for all 10 lots owners to work collaboratively to construct new protective works prior to any new development being permissible at any of these lots (unless this new development was constrained to the landward 7m of the lots). This is because it is likely that isolated protective works at one lot would be considered to have an adverse impact on neighbouring properties without protective works due to factors such as 'end effects'.

Site specific controls relating to property access for new development would also be required as discussed in Section L10.2.4, if upgraded/new protective works were not constructed at any particular lot.

L10.2.3 Fishermans Beach

Development would be feasible at most lots with the adoption of the two acceptable risk setback lines to define the location of new development (on conventional or piled foundations), without any significant negative impacts on landowners or public beach amenity. However, development would not be possible immediately south of Florence Avenue (9 Florence Avenue) and severely restricted at the lot south of Ocean Grove (11 Seaview Parade) if these setbacks were adopted.

Given the expected presence of subsurface clay and rock that is likely to limit the realisation of coastal hazards, it is considered that Applicants at these properties could submit relevant site specific (including adjacent sites where needed) geotechnical and coastal engineering advice to assess if development would be at acceptable risk if located seaward of the acceptable risk setback for piled development. Each submission could then be assessed by Council on its merits.

Site specific geotechnical and coastal engineering advice could also be utilised if any redevelopment of the Warringah Surf Rescue building or Long Reef Fishing Club Hut was to be undertaken, to enable consideration of whether this development could be at acceptable risk and located seaward of the acceptable risk setback for piled development.

That stated, it is recommended that a minimum rear (seaward boundary) building setback be adopted to ensure that this process does not lead to development so far seaward as to impact on neighbouring views and beach amenity. It is recognised that there are limitations to the 'acceptable risk' approach, in that there are other considerations besides coastal processes (such as a consistent building alignment) in defining appropriate setbacks for new development. For illustrative purposes, a 15m setback from the seaward lot boundary has been delineated in Figure L19.

Site specific controls relating to property access would also be required as discussed in Section L10.2.4.

Figure L19: 15m setback and acceptable risk lines at Fishermans Beach

Although a 15m setback would be relevant and appropriate for the 6 or 7 lots immediately north of Anzac Avenue, applying this setback at most lots further north would not enable a feasible development area. It is recommended that site specific beach amenity and visual impact advice be provided by an Applicant to justify adopted setbacks at these northern lots (if seaward of the 15m setback).

L10.2.4 General Discussion on Property and Structure Access

At some lots, although the main dwelling structure on piled foundations would be at acceptable risk, vehicular and/or pedestrian access to this structure from the road would be at unacceptable risk unless it was also piled. Referring to the area near Loftus Street in Narrabeen (as an example) in Figure L20, red arrows are drawn depicting locations where access would not be at acceptable risk (unless piled), and green arrows are drawn depicting locations where access would be at acceptable risk on conventional foundations.

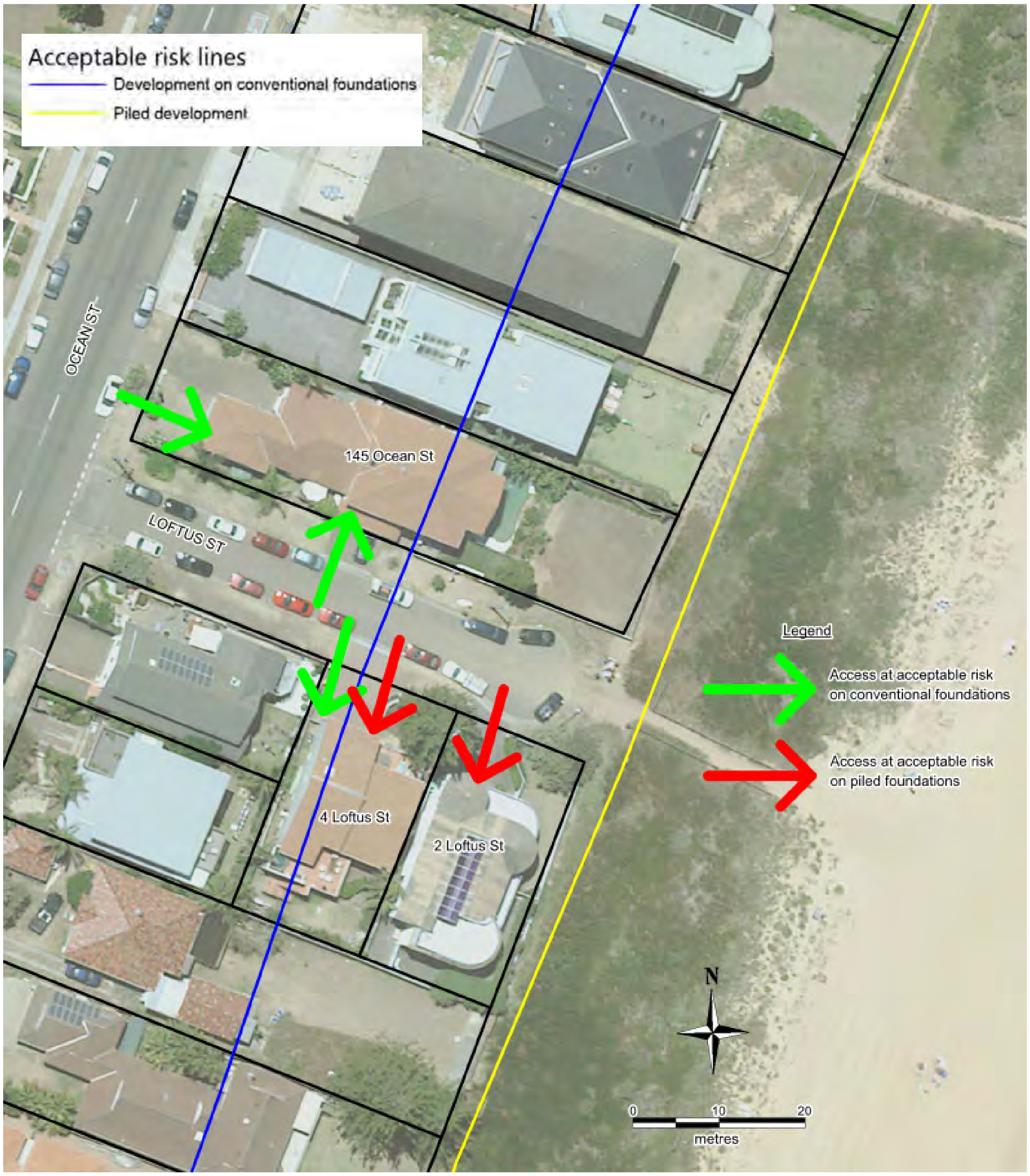

Figure L20: Illustration of access requirements in Loftus Street area at Narrabeen

It is evident that access to 2 Loftus Street would need to be piled to be at acceptable risk. A requirement for an Applicant to pile access could be a site specific control applied by Council, such that if erosion undermined any future new dwelling at this site and piling was exposed, access to the dwelling would still be possible.

At this particular 2 Loftus Street site there is also the issue that road access to reach the access point to the property may also be 'lost' (due to erosion of the road) in an event that exposed the piling at the dwelling. The road adjacent to 2 Loftus Street (given that it is not piled and is seaward of the acceptable risk line for piled foundations) is not at acceptable risk. It is understood that Council does not consider that it has an obligation to maintain road access to such a dwelling, given that the road is not at acceptable risk. It may be necessary to impose conditions (if feasible) on a future Applicant at this site to pay for the cost of maintaining road access to the property in such a situation.

At 4 Loftus Street, access at acceptable risk on conventional foundations is just possible on the north western corner of the lot. If 145 Ocean Street was redeveloped over the same footprint as existing, then access at acceptable risk on conventional foundations would be possible anywhere landward of the blue acceptable risk line, as per the two example green arrows.

Essentially, piled access to a future redeveloped dwelling would be required if that access point was seaward of the blue acceptable risk line for development on conventional foundations. Besides 2 Loftus Street, other locations at Collaroy-Narrabeen Beach where this may be an issue would be (moving north to south) at the beachfront lots immediately south of Wellington Street, immediately north of Waterloo Street, immediately north of Albert Street, and immediately south and north of Goodwin Street. This similar issue would apply at Fishermans Beach at the two most seaward lots south of Florence Avenue, and at the lot south of Ocean Grove.

Erosion of the land surrounding piled structures would be expected to impact on the amenity of the lot. To mitigate against this potential loss of amenity it is recommended that the following requirements on Applicants are considered by Council for new development seaward of the acceptable risk line for conventional foundations:

- new (piled) development should have the ground floor slab cantilevered by say a minimum distance of 900mm around the dwelling to enable access around the entire dwelling if undermined by erosion (when the structure would be elevated on piles above surrounding ground levels)[34]; and
- as discussed above, where the acceptable risk line for conventional foundations is located landward of the dwelling, access paths should cantilever or be piled to this line.

It is also recommended that for development located entirely landward of the acceptable risk line for conventional foundations, a minimum 2m additional landward setback from this line is adopted as a buffer to allow access around the seaward portion of the dwelling in the event that an erosion escarpment had extended to the acceptable risk line for conventional foundations.

[34] Alternatively, access around the dwelling could be provided by piled access paths, but this construction is likely to be substantially more costly than cantilevering.

L11. OTHER APPROACHES TO RISK DETERMINATION

The approach to defining acceptable risk herein was developed by the authors as an extension to WorleyParsons (2012a, b), in which they (in previous employment) completed a relative risk assessment to Warringah's coastal structures. This risk assessment work has also been described in Horton et al (2011) and Roberts and Horton (2011).

Familiarity with and further review of the AGS (2007a, b) procedures, recognition of the limitations of the traditional hazard lines approach, review of Australian Standards on risk[35], and support in *Guidelines for Preparing Coastal Zone Management Plans* (DECCW, 2010a) for a risk management approach led to development of the approach herein. This approach was seen as rational and robust.

Although others have defined likelihood hazard lines (for example, in the *Coffs Harbour Coastal Processes and Hazards Definition Study*), these have been defined qualitatively without reference to defined probabilities, and are not considered to be consistent with AGS (2007a, b) probabilities.

Jongejan et al (2011) considered the use of setback lines as a form of risk mitigation at Collaroy-Narrabeen Beach. They noted that defining appropriate setback lines for land-use planning purposes was a balancing act, but found that it was unclear what level of protection was facilitated by current setback lines, and whether this was sufficient from an economic perspective.

Jongejan et al (2011) presented an economic model to determine what setback lines would be optimal from an economic perspective. They concluded that:

- it is useful to define setback lines on the basis of their exceedance probabilities (as has been attempted herein)[36];
- the approach required probabilistic estimates of coastal erosion volumes (as has been attempted herein);
- an order of magnitude 1% AEP event produced an "economically efficient" setback line without sea level rise; and
- long term uncertainties (for example due to climate change) influenced the exceedance probability of "economically efficient" setback lines but only to a limited extent.

Jongejan et al (2011) used the Callaghan et al (2008) and Ranasinghe et al (2009) procedures in their analysis, to obtain probabilistic hazard lines.

Woodroffe et al (2012) further applied the Jongejan et al (2011) procedure to develop "economically efficient" setback lines for Collaroy-Narrabeen Beach. They found that these setbacks lines were located near to Ocean Street and Pittwater Road in the study area. It is considered that the approach adopted herein is more appropriate for defining acceptable risk to development from a Council perspective at this point in time.

Some of the potential limitations of Woodroffe et al (2012) included that:

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[35] Namely AS/NZS ISO 31000:2009, "Risk management - Principles and guidelines", AS 5334-2013, "Climate change adaptation for settlements and infrastructure - A risk based approach", the draft "Risk management guidelines, Companion to AS/NZS ISO 31000:2009 (Revision of HB 436:2004)" (DR HB 436) and the document HB 327:2010, "Communicating and consulting about risk".
[36] Also supported by Kinsela and Hanslow (2013).

- setbacks were defined based on economic criteria only, as opposed to the approach herein of defining acceptable risk on the basis of probabilities and consequences (which embody an economic consideration) over an appropriate design life compared to a standard developed rigorously by AGS (2007a, b);
- they assumed that those that suffer damage from storm erosion would be compensated by a third party (government, charity or other) that is unable to collect a premium for its explicit or implicit guarantee, whereas it is expected that in practice landowners would bear entirely the financial consequences of any damage to their properties;
- the economic model utilised a number of “doubtful constants” which were noted as imprecise and subject to debate, such as the discount rate and rate of return, and it was assumed that there were no market imperfections;
- there was no consideration of an appropriate design life; and
- there was no consideration of the effect of measures to reduce risk (such as piling and protective works) in the economic model.

Appendix M:
Identification and Evaluation of CZMP Management Options

CONTENTS

M1. INTRODUCTION

In *Guidelines for Preparing CZMPs* (OEH, 2013b), it is noted that CZMPs are to be prepared using a process that includes evaluating potential management options by considering social, economic and environmental factors, to identify realistic and affordable actions. OEH (2013b) also noted that CZMPs are to achieve a reasonable balance between any potentially conflicting uses of the coastal zone.

The identification and evaluation of management options herein was mostly based on a framework in the *Coastline Management Manual* (NSW Government, 1990) and is presented under the generic categories of:

- structural works (Section M2);
- sand transport (Section M3);
- dune management (Section M4;
- environmental planning (Section M5); and
- development control provisions (Section M6).

It is noted that the Intergovernmental Panel on Climate Change uses an alternative categorisation of options (first introduced in 1990), namely

- protect - continue the use of vulnerable areas by using defensive measures (eg seawalls, beach nourishment);
- accommodate - continue living in vulnerable areas by adjusting living and working habits (eg piled development, insurance, early warning and evacuation); and
- retreat – withdrawal from vulnerable areas (land use restrictions, setbacks).

M2. STRUCTURAL WORKS

M2.1 Seawalls/Revetments

Seawalls/revetments are structures built on an alongshore alignment to provide a landward limit to coastal erosion during storm events, usually to protect assets located landward. Seawalls/revetments may be vertical or stepped (for example, constructed from reinforced concrete or sandstone blocks) or sloping (for example, constructed in layers from randomly placed interlocking rock or concrete units, or pattern placed using sand-filled geotextile containers). For convenience herein, vertical/stepped structures are denoted as "seawalls" and sloping structures are denoted as "revetments".

If appropriately designed and constructed (including being founded at levels below the scour depth of the beach, that is typically below at least -1m AHD), seawalls/revetments can be effective in limiting the landward extent of storm erosion. However, there is the potential for 'end effects' (additional erosion) adjacent to seawalls/revetments which makes construction of these works at isolated lots problematic.

Details on known existing seawall/revetment protective works in the study area (which are located along most of the southern portion of Collaroy-Narrabeen Beach) were provided in Section 4.2 of the main report.

It is considered that upgrading or construction of new protective works to a specified standard would be an appropriate condition for future development along much of the southern end of Collaroy-Narrabeen Beach (south of Devitt Street), as it would not be possible to demonstrate an acceptable risk of damage to development otherwise (see **Appendix L** and Section 8.2.1 of main report) and given the extensive lengths of existing protective works in this area and management paradigms in Section 1.4 of the main report.

M2.2 Groynes

Groynes are typically constructed perpendicular to the shoreline from materials similar to seawalls/revetments (that is, rock or concrete units). These structures act to trap sand moving along a beach, and may be effective where there is a dominant direction to longshore sediment transport, promoting accretion/progradation on the updrift side. However, the downdrift side becomes starved of sand, and would be expected to recede (until such time that sand bypassed the groyne).

Groynes would only be appropriate in the study area if used in conjunction with beach nourishment. Groynes do not significantly affect onshore/offshore movement of sediment and are thus an ineffective means of managing storm erosion in the study area unless they have been used to create an additional buffer of sand updrift to meet the storm demand.

Given the potential effects on visual amenity, recession of downdrift areas, potential impacts on swimming and surfing amenity (given that groynes would be expected to extend offshore to around -4m AHD) and long timeframe until beach nourishment may be implemented in the study area (that would be required if groynes were to be implemented), groynes were not considered to be a suitable option at this time. They are also relatively expensive (see Section M3),

M2.3 Training Walls

Training walls are typically constructed (in a shore-normal direction) from rock along one or both sides of an estuary entrance to stabilise the entrance and assist in keeping it open. This can improve navigation, mitigate estuarine flooding and improve flushing of coastal lagoons with associated water quality benefits. However, at some locations it can also change the hydraulics of the entrance such that an unstable scouring mode can be instigated, leading to an increasing tidal range in the estuary and undesirable impacts, such as exposure of seagrass beds and bank erosion.

Installation of a training wall (also called a groyne) on the southern side of the entrance to Narrabeen Lagoon has been considered in the past, for example in Patterson Britton & Partners (1993). Although such a structure would be expected to reduce the infeed of northward littoral drift sand into the Lagoon entrance (and thus keep it open for longer), Council has previously resolved not to consider this option. This was due to visual impacts of the structure, impacts on beach amenity, and potential impacts on the North Narrabeen Surfing Reserve. It should also be recognised that such a structure would cost several million dollars, have a crest elevation of around 4m AHD, and need to extend offshore to seabed elevations of around -4m AHD to be fully effective in trapping sand (that is, it would need to be about 300m long).

Patterson Britton & Partners (1993) estimated that a 350m long groyne constructed at the entrance to Narrabeen Lagoon[1] would cost around $3.5 million, which could be equivalent to around $8.2 million in 2014 dollars (based on variation of the Building Price Index since 1993).

M2.4 Artificial Headlands

Artificial headlands are similar to groynes but are larger scale structures that extend into deeper water. These types of structures are not effective in managing onshore/offshore sediment transport and are hence not applicable for the study area.

M2.5 Offshore Breakwaters and Artificial Reefs

Offshore breakwaters are flexible structures that are typically constructed parallel to the shoreline from materials similar to revetments (such as rock or concrete units) and have also been built from sand-filled geotextile containers (such as the Narrowneck Artificial Reef, Gold Coast, Queensland). These structures can either have their crest level above the water (emergent breakwater) or be submerged, and act to modify the wave climate and thereby longshore sediment transport at the shoreline landward of them.

Emergent breakwaters modify the wave climate by blocking the passage of waves to the shoreline and limiting wave action to that resulting from diffraction around the extents of the structure. Submerged breakwaters (such as artificial reefs) may limit waves under calmer wave conditions and during lower tides, but are less effective in limiting the erosive action of larger waves at times of storms when there are associated elevated water levels and the structure is more submerged.

An offshore breakwater or artificial reef that was designed to guarantee protection to the study area from the action of storm swell waves and elevated water levels would likely have to be an emergent structure. This would severely impact on surfing conditions along the beach, have potential

[1] In the context of 'massive' beach nourishment.

environment impacts on the Narrabeen Lagoon entrance, create public safety issues, alter natural swimming conditions and change the natural aesthetics of the beach compartment. The length of breakwater that would be required to protect the entire beach would be a highly expensive to construct, in the order of tens of millions of dollars and not feasible for Council to fund. Furthermore, existing (and potentially upgraded) protective works along the southern end of Collaroy-Narrabeen Beach make consideration of this option unnecessary. Therefore, an offshore breakwater or artificial reef is not considered to be an appropriate management measure for the study area.

M2.6 Configuration Dredging

Configuration dredging involves the nearshore removal (and placement) of sand from the seabed in a manner that changes the way that storm waves act on the coastline. This is achieved by seabed level modifications that redirect the orientation of wave attack away from erosion prone areas.

The effectiveness of configuration dredging for the study area is limited by the number of wave directions that are possible in an open coast situation. Changes in seabed levels would also have the potential to adversely impact on surfing and swimming conditions. The existence of rock reef would also limit its viability. Therefore, configuration dredging was not considered an appropriate management measure for the study area.

M3. SAND TRANSPORT

Sand transport management measures include beach scraping, Narrabeen Lagoon entrance clearance (beach sediment recycling), and beach nourishment. These measures are discussed in **Appendix I** (Sections I2.7.5 and I2.7.6) and Section 8.3 of the main report.

To add a sufficient quantity of sand to Collaroy-Narrabeen Beach so that protective works would be unnecessary to protect development (so-called "massive" beach nourishment), in the order of 2,600,000 m^3 (4,200,000 tonnes) of native beach sand has been estimated to be required to provide initial protection, with ongoing nourishment required to replenish sand loss over time (Patterson Britton & Partners, 1993). Based on this volume of sand (that is, assuming that the sand source was fully compatible with the native beach sand), initial (present day) costs would be in the order of $130 million using land-based sand sources. Even using lower cost offshore sand sources (which currently cannot be accessed under NSW legislation) the costs would still be prohibitive, in the order of $65 million (present day).

Massive beach nourishment may lead to more frequent and prolonged closure of the Narrabeen Lagoon entrance (Patterson Britton & Partners, 1993). Some experts (such as Dr Andrew Short) disagree, stating that massive nourishment would make no difference to the choking of the entrance, noting that although the beach would be wider the entrance channel (tidal inlet) would just get longer if this nourishment happened. Although Dr Short may be correct, it is considered to be more likely that the presence of additional sand near the entrance would feed additional sand into the Lagoon through surf zone and wind driven processes. Also, the frictional resistance of a longer entrance channel would be expected to be greater, reducing the effectiveness of the channel to self-scour. It is certainly the case that massive beach nourishment, if not neutral to sand infeed to the entrance channel, could only act to potentially increase it.

The possibility of more frequent and prolonged Lagoon closure is considered to be supported by the work of Morris (2010), who found that sediment supply was a factor (although a secondary effect) in Lagoon closure.

If there was more frequent and prolonged Lagoon closure, this would have significant adverse impacts on lagoon flooding, water quality, ecology and recreation. This could also lead to consideration of the construction of a training wall (groyne) at the lagoon entrance to capture sand, which itself would have impacts on beach amenity, swimming and surfing conditions.

In addition, massive beach nourishment would require modification to existing stormwater outlets along the beach. Patterson Britton & Partners (1993) considered that the following modifications to existing outlets would be necessary to accommodate a widened beach profile:

- Collaroy Street Outlet – extend offshore;
- Frazer Street Outlet – improve energy dissipation and scour protection at outlet and discharge into purposely formed swale area in the newly created dune;
- Ramsay Street Outlet – extend offshore; and
- Goodwin Street Outlet – improve energy dissipation and scour protection at outlet and discharge into purposely formed swale area in the newly created dune.

The proposed beach nourishment considered herein (if funding and sand sources become available) can be described as "moderate" beach nourishment in order to maintain beach amenity (as opposed to the massive beach nourishment providing protection to development). If moderate beach nourishment was undertaken, the initial volume of sand placed would need to be sufficient to restore beach amenity at that time and to accommodate losses from natural processes and future sea level rise over say a 10 year renourishment cycle.

Patterson Britton & Partners (1993) estimated that a volume rate of 70m^3/m would need to be placed on the sub-aerial[2] beach profile to provide satisfactory beach amenity based on a review of historical beach profiles and consideration of the frequency of exposure of protective works during storms. If the width of sub-aerial nourishment was applied over the full beach profile (that is, including the sub-aqueous profile[3]) this volume rate would be equivalent to around 270m^3/m if an average dune height of 6m AHD was adopted. Application of this volume rate to the entire Collaroy-Narrabeen Beach length of 3,600m results in a nourishment volume of around 1,000,000m^3 to restore beach amenity.

To accommodate sediment losses from natural processes causing beach recession of 0.05m/year (**Appendix I**), around 1,100m^3/year would be required to be added to the beach compartment or around 11,000m^3 to accommodate losses over a 10 year renourishment cycle.

The nourishment volume required to accommodate sea level rise is dependent on the implementation time as the rate of sea level rise varies with time (IPCC, 2013a). Implementation of moderate beach nourishment at some future date would require a sediment volume sufficient to accommodate beach recession caused by sea level rise from the present time to that date and an additional sediment volume to accommodate future beach recession due to sea level rise over say a 10 year renourishment cycle.

Estimates of the total initial beach nourishment volume associated with moderate beach nourishment implemented at different times in the future are provided in Table M1. It should be noted that the actual volume of sediment extracted from the sand source would be dependent on its compatibility with the native beach sand. A beach nourishment scoping study (Aecom, 2010) determined that for every 1m^3 of native beach sand required on Collaroy-Narrabeen Beach, 1.15m^3 of sand from the preferred source for the study at Cape Banks (offshore of the entrance to Botany Bay) was required[4].

Table M1: Moderate beach nourishment volume requirements at future implementation times

Implementation Date	Initial Beach Nourishment Volume (m^3)	
	Native Beach Sand	Source Sand (Cape Banks)
2014	1.06 M	1.22 M
2020	1.08 M	1.24 M
2030	1.12 M	1.29 M
2040	1.17 M	1.35 M
2050	1.22 M	1.40 M

Following an initial beach nourishment campaign, subsequent renourishment campaigns undertaken every 10 years would require a volume of between around 50,000m^3 to 70,000m^3 of native beach sand (or around 58,000m^3 to 81,000m^3 of sand sourced from Cape Banks) depending on the rate of future sea level rise projected at the implementation date.

[2] Meaning 'under the air' or the portion of the active beach profile above 0m AHD.
[3] Meaning 'below the water' or the portion of the active beach profile below 0m AHD.
[4] The sand sources identified in Patterson Britton & Partners (1993) were offshore from the entrance to the Hawkesbury River in Broken Bay and had comparable overfill factors of between 1.1 and 1.3.

Aecom (2010) estimated that if beach nourishment was undertaken as a collaborative exercise between Councils responsible for 31 beaches in the greater metropolitan region of Sydney, this would cost around $\$25/m^3$ on average[5] if a central source of sand at Cape Banks (offshore of the entrance to Botany Bay) was utilised with sand extracted by specialised dredging equipment[6] mobilised from overseas. This would equate to costs for an initial beach nourishment campaign in the order of $30 million to $35 million and costs for renourishment campaigns undertaken every 10 years being in the order of $1.5 million to $2.0 million. It is evident that significant funding outside Council resources would be required for moderate beach nourishment to be implemented.

To improve effectiveness, beach nourishment material could be contained within areas most at risk from storm erosion (south of Devitt Street at Collaroy-Narrabeen Beach) by constructing a groyne at Devitt Street extending some 500m out to the limit of substantial sediment movement under wave action. This option was noted in combination with moderate beach nourishment south of the groyne in Patterson Britton & Partners (1993) at a cost of around $15.6 million in 1993 dollars for the groyne only. Based on the variation of the Building Price Index since 1993, this could be equivalent to around $36.5 million in 2014 dollars for the groyne, which is relatively expensive.

A groyne at Devitt Street could have adverse impacts on areas immediately to the north due to recession caused by interruption of longshore sediment transport to the north. This would include the foreshore reserve areas north of Devitt Street but the rate of erosion could be attenuated by the maintenance of dune vegetation and the placement of sand periodically cleared from entrance of Narrabeen Lagoon on the northern side of the groyne.

[5] This includes direct costs of dredging and nourishment and project costs, including survey, sediment sampling and analysis, geotechnical investigation, environmental assessment and design and tender documentation.
[6] A large Trailer Suction Hopper Dredger (TSHD).

M4. DUNE MANAGEMENT

Dune management involves the maintenance of dunes and their vegetative cover. Well maintained dunes hold a reserve of sand on the beach to cater for storm erosion and provide a barrier to oceanic inundation. The establishment and maintenance of dune vegetation also minimises loss of windblown sand from the beach compartment.

Management of coastal dune areas in developed areas typically involves:

- control of public access (pedestrian and vehicular) to dune areas by the use of fencing and formalised beach access tracks;
- rehabilitation of degraded dune areas involving weeding and planting of native plant species;
- controlling land use in dune areas by applying development controls; and
- prevention or minimisation of scour caused by stormwater outlets by:
    - siting these structures away from beach areas where possible (for example, by discharging over rock platforms, subject to environmental assessment);
    - provision of energy dissipating structures (such as rock blankets) at beach outlets; or
    - discharge of stormwater flows into drainage swales located in back beach areas.

Along Collaroy-Narrabeen beach, established vegetated dune areas exist north of Devitt Street. These areas should be maintained. South of Devitt Street there is little opportunity for dune vegetation to be established due to the proximity of private development to the beach. That stated, a buffer of dune vegetation has been established adjacent to the public parking area north of the Collaroy Services Beach Club. South of this point, the landward edge of the beach berm is defined by a vertical seawall.

Along Fishermans Beach, dune vegetation is limited, again due to the proximity of private development to the beach (north of Anzac Avenue), and proximity of paths and car parking areas to the beach (south of Anzac Avenue). Existing areas of dune vegetation should be maintained and opportunities taken to increase the coverage of dune vegetation in other areas where possible.

All dune management works should be undertaken in accordance with the principles of the *Coastal Dune Management Manual* (Department of Land and Water Conservation, 2001).

M5. ENVIRONMENTAL PLANNING

M5.1 Land Use Zones

The definition of land use zones is a basic method available to Councils for controlling the nature of land use and development. Land use zones are implemented through a Local Environment Plan (LEP) and its associated land zone mapping. The document structure and available land use zones and their descriptions within an LEP are prescribed by the NSW Department of Planning in their Standard Instrument LEP and associated LEP practice notes.

The current land use zones applied to beachfront properties along Collaroy-Narrabeen and Fishermans Beach predominantly comprise either Zone R2 – Low Density Residential (to facilitate private residential development) or Zone RE1 – Public Recreation (to facilitate provision of foreshore reserve areas). Localised areas are also zoned either Zone B1 – Neighbourhood Centre or Zone B2 – Local Centre to provide for small-scale commercial development.

An alternate zoning that could be considered is the use of environmental protection zones, which are included in the Standard Instrument LEP and are described in LEP guidance notes (Department of Planning, 2009a). The Standard Instrument LEP contains four environment protection zones specifically for land where the primary focus is the conservation and/or management of environmental values. The zones provide for varying levels of environmental protection from Zone E1 to E4.

It is considered that rezoning of beachfront properties would not facilitate future coastal management objectives for Collaroy-Narrabeen and Fishermans Beach. As such, it is recommended that the current zonings be retained, and that amendments to the *Warringah LEP 2011* (to include acceptable risk and beach amenity setbacks, for example) and specification of associated controls within the *Warringah Development Control Plan* be undertaken.

M5.2 Buffer Zones

The main function of a buffer zone is to provide a width of beach that can be stabilised with vegetation to accommodate short-term shoreline fluctuations caused by storm erosion and subsequent beach recovery. This is typically achieved on undeveloped coastlines through appropriate zoning in LEP's (such as for public recreation). However, in areas with high levels of existing development this is difficult to implement as current legislation protects the "existing use" rights of existing development, which can continue to exist and be subject to renovations and additions despite rezoning of land by Councils. The only other option available for Council to create buffer zones is to acquire private land, which is currently considered to be cost-prohibitive in the study area (refer Section M5.3).

North of Devitt Street at Collaroy-Narrabeen Beach, an effective vegetated buffer zone between the beach and development currently exists.

M5.3 Property Purchase

Acquisition of private property by Councils can be achieved by 'voluntary purchase' (when a landowner voluntarily offers their property for sale to the government) or by purchase on the open market. These types of schemes aim to return property that is considered to be at-risk back into the control of Councils, who can rezone the land and/or establish a coastal buffer zone (refer Section M5.2).

However, in practice voluntary purchase is unlikely to be realised in the study area as the market for beachfront property is typically strong and owners have no incentive to arrange for sale of their property off the open market. The end result is that Councils need to compete with other private buyers as properties are sporadically offered on the open market, which requires significant capital investment and may take decades before an at-risk length of coastline is completely acquired.

Council has purchased some properties in the past, the last being two in 2005 at a total cost of $5.2 million. Council however cannot afford to continue to purchase at-risk beachfront properties. As noted in Section 4.6.2 of the main report, the current market value of private property in the study area is around $717 million. That figure is about four times Council's current entire yearly expenditure, and over 350 times more than the NSW Government typically spends annually in the entire State through its Coastal Management Program (about $2 million per annum). Property purchase is therefore considered to be a cost-prohibitive management option that would not be pursued by Council.

M5.4 Planned Retreat

Planned retreat is a strategy that can be used to allow development to exist on a receding coastline for a period of time until the risk to property becomes unacceptable. The trigger for actioning planned retreat can be either time-based (occupation of an area is allowed until a certain date) or trigger-based (based on physical realisation of coastal hazards, such as when an erosion escarpment encroaches within a specified buffer distance from a dwelling). If implemented on an existing undeveloped coastline, planned retreat can be facilitated by construction of relocatable buildings, which can be readily moved when development consent lapses and landowners are required to cease occupation and retreat further landward.

In the case of a highly developed coastline such as the study area, this approach becomes problematic to implement as private landowners would be required to demolish their existing dwellings and completely rebuild at significant cost. There a number of issues with the broad-scale implementation of planned retreat in the study area, including:

- current legislation protects the existing development, which can continue
- retreat of dwellings is limited by the size of the lots;
- the likely financial impacts on landowners;
- existing protective works would remain if such a policy was applied, and land ownership would not change, so beach amenity would not necessarily improve.

M6. DEVELOPMENT CONTROL PROVISIONS

M6.1 Preamble

Development control provisions, in addition to normal building industry standards, can be enforced to incorporate the management of coastal hazards into new development applications. These controls can be implemented through planning instruments including Local Environment Plans (LEPs) as statutory provisions, and Development Control Plans (DCPs). Development control provisions can include:

- definition of setback lines, seaward of which development is restricted;
- requirements to provide coastal protection works if development is proposed in an area particularly prone to current or future coastal hazards (particularly where there are existing protective works in the study area);
- requirements to provide appropriate foundations (such as deep piling) beneath structures to accommodate storm erosion;
- measures to minimise damage from coastal inundation, such as minimum floor levels and use of water resistant materials;
- dune management measures, to establish vegetated dunes in order to protect the development or to prevent damage to existing dune areas from construction or land use;
- requirements to return any sand excavated as part of construction activities to the active beach system;
- maintenance of an access route to facilitate emergency protection; and
- design of structures such that they are relocatable.

Council has historically applied several of the above provisions to development along Collaroy-Narrabeen Beach and Fishermans Beach. These include setback lines and foundation design requirements.

M6.2 Setback Lines

As discussed in **Appendix L**, it is recommended that setbacks for future development in the study area be defined based on consideration of acceptable risk and other matters such as the alignment of existing buildings.

M6.3 Coastal Protection Works

The requirement to construct coastal protection works as part of a new development provides a means by which development (that would not be approved otherwise due to consideration of acceptable risk) can be permitted in coastal risk areas. This type of control has potential application for development south of Devitt Street at Collaroy-Narrabeen Beach. Provisions imposed on new development proposed within certain zones could require either upgrade of the existing seawall or construction of a new seawall to fill gaps in existing protection. This is consistent with the requirement for beachfront landowners to submit a development application to protect their property with protective works. Such applications, including those that may be associated with imposed controls on development, would need to be assessed by Council on their merits. To provide a basis for merits assessment and define a standard for the design and construction of protective works, it is considered that a policy document would need to be prepared to supplement any development control provisions.

M6.4 Foundation Design

Controls on the design of foundations for development are included in Section E9 of the *Warringah DCP*. It is considered that development controls for design of foundations are an appropriate measure for continued management of future new development or redevelopment of existing dwellings in coastal risk areas.

M6.5 Floor Levels

Section E9 of the *Warringah DCP* also includes a requirement to construct development with a suitable floor level or in a manner that minimises the risk of coastal inundation for severe coastal storms occurring over the next 50 years. An expanded clause should be retained within the DCP.

M6.6 Dune Management Measures

As discussed above (refer Section M4), the establishment of vegetated dunes in areas of Collaroy-Narrabeen Beach south of Devitt Street and along Fishermans Beach is difficult due to proximity of existing development to the beach. As such, any development controls stipulating dune management measures would impose an impractical requirement on landowners. Controls relating to maintenance of vegetation generally could be included.

M6.7 Sand Preservation

Given the position of beachfront lots along Collaroy-Narrabeen Beach and Fishermans Beach in relation to what may have been a natural dune area, any excavation for development is likely to encounter sandy subsurface material that is compatible with the native sand in the active beach system. It is considered that a requirement to return any surplus clean sand to the beach as part of construction activity is an appropriate condition to build up reserves of beach sand for storm erosion.

This would be consistent with Council's current practice of undertaking opportunistic beach nourishment with suitable sand sourced from building sites.

M6.8 Emergency Access Routes

The maintenance of an access route for installation of emergency coastal protection works is a relevant consideration where approval has been obtained for placement of such works, and can be placed as a consent condition for such works if required.

The establishment of a foreshore access corridor for the purposes of long term protective works maintenance (for example to repair damage following major storms) is considered to be an appropriate measure for Collaroy-Narrabeen Beach south of Devitt Street . This would be most effectively implemented over time by incorporating an access width provision into building setback lines (refer Section M6.2).

M6.9 Relocatable Buildings and Planned Retreat

As discussed above in Section M5.4, the adoption of a planned retreat strategy is not considered to be appropriate for the study area, which contains high levels of existing development on small lots.

Appendix N:
Financial Evaluation of Potential CZMP Management Options

CONTENTS

Page N

N1. INTRODUCTION

N1.1 Background

In this Appendix, a broad qualitative assessment of the financial impacts of various CZMP management options has been presented. Financial impacts were assessed relative to the base case of the status quo (existing state of affairs), that is present day beach conditions and Council's current coastal management regime continuing into the future, which essentially:

- relies on 1991 Hazard Line setbacks and piled foundations as development controls as required (which mainly affects beachfront residents south of Devitt Street at Collaroy-Narrabeen Beach);
- does not have beach nourishment as a currently practiced management option (of the magnitude that would maintain beach amenity over the long term); and
- has no requirements for any protective works as a development control.

This base case would essentially (over the long term) lead to:

- potential damage to development (reducing land values and hence reducing NSW land taxes[1]); and
- reduction in beach amenity over time, reducing visitation to the study area and hence potentially Council revenue (due to reduced parking meter fees[2]) and local business revenue (due to less patronage). Federal tax revenue is likely to be unchanged in this case as although Council would contribute less GST[3] and local businesses would contribute less GST and company tax, it is likely that spending in the area would be substituted to other activities in other parts of the local economy[4].

Negative financial impacts are defined herein as an increase in costs/expenses, reduction in income, reduction in asset value and/or decrease in Council services (compared to the base case described above). Positive financial impacts are defined herein as a reduction in costs/expenses, increase in income, increase in asset value and/or increase in Council services (again compared to the base case). Except in the case of Council services, it should be recognised that some options have non-monetary impacts that have not been considered (such as effects on dune vegetation and associated fauna, and effects on personal well-being and lifestyle).

The potential financial impacts were assessed for a number of stakeholder groups, namely:

- Council;
- beachfront landowners (residential and business);
- wider Warringah ratepayers that were not beachfront landowners;

[1] Land taxes are calculated as a percentage of the land value if sufficiently high and not the principal place of residence.
[2] It is possible that Council revenue would be unchanged if people who avoided the study area due to poor beach amenity instead chose another beach in Warringah LGA to visit.
[3] Councils are exempt from both Commonwealth Income Tax and Capital Gains Tax. Council does however have to comply with both Fringe Benefits Tax (FBT) and Goods and Services Tax (GST).
[4] That is, it is assumed that people who avoided the study area due to poor beach amenity would spend an equivalent amount at other businesses for alternative recreational activities. Even if the Federal taxation contribution of the Warringah Council area diminished, this would be a small component of overall federal government revenue.

- wider local Warringah businesses that were not beachfront (located in the vicinity of the study area, such as tourist accommodation, shops and restaurants);
- wider Warringah businesses;
- general public outside of Warringah;
- NSW Government (affected by land tax revenues, for example[5]); and
- Federal Government (affected by business tax revenues, for example[6]).

The qualitative financial impact assessment is presented in tables with colour coding in Section N2 (for proposed options) and Section N3 (for considered and dismissed options). The colour coding used is provided in Table N1.

Table N1: Colour coding to identify financial impacts herein

Financial Impact	Colour
Positive	Green
Neutral	Yellow
Negative	Red
Uncertain	Grey

It should be recognised that the assessment of financial impacts herein was not undertaken in order to directly determine suitable CZMP options, given that these options were generally formulated based on Council's management paradigms (as well as engineering, legal, social and planning factors). That is, the assessment of financial impacts herein was undertaken to illustrate the financial consequences of selecting the proposed and "considered but dismissed" options. Given this, the analysis was relatively high level and qualitative and there was no attempt to quantify the cost benefit ratios for specific options.

There are additional complexities and feedbacks that could be assessed in a more detailed analysis, but given (as noted above) that consideration of financial impacts did not generally drive the selection of the proposed CZMP options, this is not considered to be necessary.

N1.2 Impacts of Beach Nourishment

For the proposed option of beach nourishment being undertaken to maintain beach amenity (Table N3), potential positive/negative impacts are uncertain as they would depending on the distribution of funding (between NSW Government, Council, beachfront landowners and wider Warringah ratepayers) and the scale of required works. That stated, there are numerous investigations that have indicated a positive (greater than unity) benefit:cost ratio for beach nourishment works, such as Aecom (2010), who assessed the costs and benefits of beach nourishment of Sydney's beaches (in particular Collaroy-Narrabeen Beach, Manly Beach and Bate Bay) and found substantial positive benefits after environmental, economic and social evaluations over a 50 year time period.

[5] Although it is recognised that any changes to NSW land tax revenue related to the study area would be a very small percentage of total NSW land tax revenue.
[6] Although it is recognised that any changes to Federal tax revenue related to the study area would be a very small percentage of total Federal tax revenue.

Aecom (2010) found that a nourishment programme for Collaroy-Narrabeen Beach would be economically viable. The main economic benefits were associated with the avoidance of flow-on effects (costs) from:

- loss of beach amenity to beach visitors, local residents and businesses and government revenues; and
- potential loss of property[7].

Specifically, the cost-benefit analysis for Collaroy-Narrabeen Beach completed by Aecom (2010) demonstrated a net present value of $42M, a benefit-cost ratio of 1.6 (medium value for money) and an economic internal rate of return of 12%. The high economic rate of return for Collaroy-Narrabeen Beach was due to the intensely developed shoreline.

The main quantified benefits were the avoided loss of:

- residential property values attributable to beach amenity (45% of total quantified benefits);
- value of residential properties located within hazard lines (38%);
- expenditure by beach visitors (8%); and
- rates revenue from residential property values within walking distance of the beach as a result of lower property values (4%)[8].

Sensitivity analysis completed by Aecom (2010) showed that the economic viability was reasonably robust, but not economically viable in the most extreme sensitivity test (where project benefits were reduced by 30% and project costs were increased by 30%).

Aecom (2010) noted that the first gate in the establishment of a business case to NSW Treasury to seek funding to progress beach nourishment was a Strategic Gateway Review. The status of this review is unknown. It is emphasised that additional cost benefit analysis would be required to assess the economic feasibility of beach nourishment in the study area.

Other studies of interest in relation to economic valuation of beaches and beach nourishment include:

- Kirkpatrick (2011, 2012), who considered the economic value of natural and built coastal assets and provided an overview of environmental economic valuation techniques. For natural assets, beaches (including visitation – residential and tourism, and surfing) were considered.

- Anning (2012), who sought to estimate the economic value of selected Sydney beaches (including Collaroy-Narrabeen Beach), in order to provide the necessary information to allow local and State government agencies to identify the most appropriate management response

[7] Beach nourishment to maintain beach amenity essentially maintains the present (base case) beach width, which does not change the degree of property protection compared to the present, but can be considered to provide some property protection in the long term (or to avoid potential loss of property) compared to the base case of not undertaking beach nourishment. Aecom (2010) would need to be assessed in more detail to determine if their analysis was directly applicable to the investigation reported herein.
[8] It is considered that this benefit may have been overstated by Aecom (2010) as the total pool of rates income a Council receives is essentially fixed at each rates cycle and does not depend on the value of properties in the LGA. Therefore, if (for example) beachfront property lowers in rateable value, this does not reduce Council's overall rates income, but means that non-beachfront property owners have to pay a greater share of the fixed overall rates burden. That stated, NSW Government land tax revenues could reduce if property land values reduce for rented properties (land tax is not applied to a principal place of residence).

to projected climate change impacts. He suggested that there was a strong economic argument for beach nourishment at Collaroy-Narrabeen Beach.

- Sydney Coastal Councils Group Inc (2013), who provided estimates of the value of a beach day, willingness to pay to avoid future erosion impacts, and the influence of beaches and erosion risk on coastal property markets (with Sydney as the focus, including Collaroy-Narrabeen Beach as one of three case study sites). The research sought to answer the questions as to what the partial or total loss of beaches would mean for tourism and recreation revenue streams, the local property market and for beach users.

- There are numerous United States investigations supporting the economic benefits of beach nourishment, as summarised in American Shore & Beach Preservation Association [ASBPA] (2007). The emphasis in these studies is the importance of foreign tourism in the United States (US), with the tourism/travel industry being the nation's largest employer and foreign revenue earner, and the most popular destinations among foreign visitors being beaches.

  ASBPA (2007) considered that beach tourists in the US contribute to taxes that outweigh the cost of beach nourishment by many times. Houston and Dean (2013) also noted that wide beaches produced by beach nourishment have won US and worldwide fame, attracting huge numbers of tourists and producing significant economic returns much greater than the cost of the nourishments.

  ASBPA (2007) also stated that increased foreign competition could endanger US dominance in the foreign beach tourism market. ASBPA (2007) considered that if US beaches disappeared, tourists would go elsewhere, reducing US tax revenue and endangering the 1.4 million tourism related small businesses in the US. This argument may be applicable to Sydney or Australia generally (which may be particularly significant for major tourist beaches such as Bondi and Manly), but further investigations would be required to assess the significance of tourism to the study area.

Aecom (2010) and the other studies noted above have been referred to for illustrative purposes, and their specific relevance to the study area and proposed CZMP options has not been established.

It is recommended that a detailed cost benefit analysis is completed in the future on the option of beach nourishment, to quantify the impacts on various stakeholders and Warringah overall.

N2. QUALITATIVE FINANCIAL ASSESSMENT OF PROPOSED OPTIONS

Two options are considered in this Section, namely:

- undertaking the private development controls proposed (setbacks, piled foundations and new/upgraded protected works funded by landowners where required) without any beach nourishment[9] (Table N2); and
- undertaking beach nourishment to maintain beach amenity in addition to the above (Table N3)[10].

Table N2: Financial impacts for private development controls proposed (setbacks, piled foundations and new/upgraded protected works funded by landowners where required) without any beach nourishment

Stakeholder Group	Qualitative Financial Impact on Stakeholder Group
Council	• meets Council's duty of care
Beachfront landowners (residential and business)	• allows new development with risk that is acceptable, so reduces likelihood of large one-off losses to landowners due to structural damage of new development from coastal storms (positive impact due to reduced expenses) • for some there would be initial additional costs (short term negative financial impact due to increased expenses) if redevelopment occurred, eg if piling or protective works were required, but this is a landowner choice presumably based on an assessment of the perceived overall benefits • the costs of works would generally be expected to be far less than (in the order of 5% to 10% of) the market value of the beachfront dwellings at risk • furthermore, it would be expected that the market and land value of the property would increase as a result of such works (it is recognised that this does cause some negative impacts due to higher rates and higher land tax where applicable)
Wider Warringah ratepayers (not beachfront)	• allows redevelopment where there is acceptable risk, thus keeping the number of rateable properties as high as possible (neutral impact) • given financial impacts on Council are positive (see above) then this is a consequential positive impact on ratepayers (due to potentially reduced expenses) who are affected by Council's financial stability
Local Warringah businesses (not beachfront)	• neutral (has little effect as essentially maintaining the current local population) • beach amenity would be expected to reduce over time (with protective works in place and no beach nourishment undertaken) leading to less visitation to area and less income, but this is neutral relative to the base case
Wider Warringah businesses	• neutral (has little effect)
General public outside of Warringah	• neutral (has little effect)
NSW Government	• if anything impact is positive, mirroring the positive impact as per Council, and also due to enhancement of land values and thus potentially increasing land tax revenue
Federal Government	• if anything impact is positive, as beachfront businesses presumably have relatively more income (as they are less likely to be damaged) and thus provide greater tax revenue, and higher market values increase capital gains taxes (that is, economic activity is likely to be stimulated in the region relative to the base case)

[9] Given that the base case also does not have beach nourishment to maintain beach amenity, the effect of not including beach nourishment in this option is neutral.
[10] Beach nourishment would not be undertaken without undertaking the private development controls proposed.

Table N3: Financial impacts for option of beach nourishment to maintain beach amenity, in addition to Table N2 controls

Stakeholder Group	Qualitative Financial Impact on Stakeholder Group
Council	• Impacts would depend on the level of funding provided by Council • with beach amenity maintained, visitation to area would be expected to be maintained (a positive impact compared to the base case of not undertaking nourishment with associated loss of public/tourist visitation due to a less attractive area), a positive impact on beach parking revenue • that is, the base case cost (reduced income) of the loss of visitation would be avoided • there would also be positive impacts as per Table N2.
Beachfront landowners (residential and business)	• impacts would depend on the level of funding provided by landowners • option would be expected to maintain property market values compared to values reducing for the base case of not undertaking nourishment (a positive impact, partially offset by higher land value and hence higher rates and higher land tax where applicable) • there would also be positive impacts as per Table N2
Wider Warringah ratepayers (not beachfront)	• impacts would depend on the level of funding provided by ratepayers and Council
Local Warringah businesses (not beachfront)	• with visitation maintained (a positive impact compared to the base case), there would be expected to be increased income compared to the base case
Wider Warringah businesses	• some positive impact as general visitation to LGA would be enhanced relative to the base case, leading to increased income compared to the base case
General public outside of Warringah	• neutral (has little effect)
NSW Government	• impacts would depend on the level of funding required by NSW Government • there could be a positive impact on land tax revenues if this option was undertaken
Federal Government	• positive impact due to maintenance of business income tax and beachfront landowner capital gains tax revenues (base case would have reduced revenues due to lower attractiveness of area for former, and lower market values for latter) • that is, economic activity is likely to be stimulated in the region relative to the base case

N3. QUALITATIVE FINANCIAL ASSESSMENT OF CONSIDERED BUT DISMISSED OPTIONS

Note that for the three options considered in this Section, it was assumed that beach nourishment would not be undertaken. The three options considered were:

- beachfront landowners not being permitted to redevelop (and without any form of compensation)[11], see Table N4;
- Council purchasing beachfront property as it came on to the market[12] (Table N5); and
- Council funding upgrading and infilling of protective works south of Devitt Street at Collaroy-Narrabeen Beach (Table N6).

Table N4: Financial impacts if beachfront landowners were not permitted to redevelop (and without any form of compensation)

Stakeholder Group	Qualitative Financial Impact on Stakeholder Group
Council	• potential opisition from property owners
Beachfront landowners (residential and business)	• potential large negative impact, as property market value could be expected to substantially diminish (partially offset by lower land value and hence lower rates and lower land tax where applicable)
Wider Warringah ratepayers (not beachfront)	• small negative impact as beachfront rateable land values would reduce, thus placing an additional burden (increased expense) on other ratepayers to cover required rates • use of Council funds for legal battles may also require reduction (savings) in Council services in other areas\
Local Warringah businesses (not beachfront)	• neutral (has little effect)
Wider Warringah businesses	• neutral (has little effect)
General public outside of Warringah	• neutral (has little effect)
NSW Government	• some negative impact with reduced land tax revenue
Federal Government	• mostly neutral (some negative impact with potential reduced landowner capital gains tax revenue)

If compensation was provided for the option in Table N4, this would be a negative financial impact on the party that funded the compensation, and the impact on beachfront landowners may change to neutral (compared to Table N4) if the compensation funding was adequate (that is, commensurate with market value prior to restrictions on development being applied).

[11] It is assumed in this option that existing development and protective works would remain under existing use rights. That is, restricting future development opportunities would not be expected to lead to a change in ownership of private land to public, for example. If this option was considered it would initially apply at the most at risk areas (southern end of Collaroy-Narrabeen Beach and parts of Fishermans Beach), and could then apply more widely as long term recession was realised.
[12] This would mean that private land, when purchased, would become public land. Different analyses could be applied if different parties purchased the land, such as the NSW Government.

Table N5: Financial impacts if Council purchased beachfront property as it came on to the market

Stakeholder Group	Qualitative Financial Impact on Stakeholder Group
Council	• relatively large costs would be required • beachfront property prices may also relatively increase as the pool of available properties reduced due to greater exclusivity
Beachfront landowners (residential and business)	• positive impact (maintained or increased market values) compared to base case of reduced market values for those that sell • this could be partially offset by higher land value and hence higher rates and higher land tax where applicable for those that do not sell
Wider Warringah ratepayers (not beachfront)	• small negative impact as pool of beachfront rateable properties values would reduce (partially offset by expected increase in land value of remaining beachfront property), thus placing an additional burden (increased expense) on other ratepayers to cover required rates • use of Council funds for purchases may also require reduction (savings) in Council services in other areas
Local Warringah businesses (not beachfront)	• uncertain • negative impact of less local residents (reduced income) potentially offset by • increased public/tourist visitation due to a more attractive beach (with more public beach area and open space)
Wider Warringah businesses	• neutral (has little effect)
General public outside of Warringah	• neutral (has little effect)
NSW Government	• some negative impact with reduced land tax revenue (with private land converted to public land) • partially offset by increased value of remaining land
Federal Government	• some negative impact with reduced business income tax (if any beachfront businesses were converted to public land) and landowner capital gains tax revenue due to less private properties • partially offset by increased value of remaining properties • neutral overall as Warringah Council area contribution to overall federal government revenue is small

Table N6: Financial impacts if Council funded upgrading and infilling of protective works south of Devitt Street at Collaroy-Narrabeen Beach

Stakeholder Group	Qualitative Financial Impact on Stakeholder Group
Council	• relatively large costs would be required
Beachfront landowners (residential and business)	• positive impact (maintained or increased market values and less risk of damage to development) compared to base case of reduced market values and increased risk of damage (partially offset by the higher land value causing higher rates and higher land tax where applicable)
Wider Warringah ratepayers (not beachfront)	• use of Council funds for works may require reduction (savings) in Council services in other areas
Local Warringah businesses (not beachfront)	• neutral (has little effect as essentially maintaining the current local population) • if beach amenity reduced over time (eg with protective works in place and if no beach nourishment was undertaken) may be some negative impacts due to reduced income with less visitation to area
Wider Warringah businesses	• neutral (has little effect)

General public outside of Warringah	• neutral (has little effect)
NSW Government	• if anything impact is positive due to enhancement of land values and thus enhancing land tax revenue
Federal Government	• if anything impact is positive, as beachfront businesses presumably have relatively more income (as they are less likely to be damaged) and thus provide greater tax revenue, and higher market values increase capital gains taxes • that is, economic activity is likely to be stimulated in the region relative to the base case

N4. DISCUSSION

The proposed option of private development controls (setbacks, piled foundations and new/upgraded protected works where required) is considered to have positive financial impacts on Council, beachfront landowners, wider Warringah ratepayers, and the NSW and Federal Government, with no significant negative financial impacts on any stakeholder groups (Table N2). Therefore, this financial analysis generally supports the adoption of this option (recognising, as noted in Section N1.1, that the option was not selected on the basis of this analysis).

Although the financial analysis generally supports the adoption of private development controls, it is recognised that in some cases the construction of protective works may be complicated by the need for owners of multiple lots to band together to build protective works collectively. Gaining cooperation within a group of residents may be difficult as they may have differences in their expectations and tolerances of risk, access to funds and desire to promote development. Council may need to consider providing incentives to assist neighbours form coalitions such as offering a member of staff to assist in offering advice and coordinating responses.

The proposed option of beach nourishment to maintain beach amenity would require further analysis to assess financial impacts once the level of funding required by Council, beachfront landowners, wider Warringah ratepayers and the NSW Government was determined (Table N3). It is expected that financial impacts on Warringah businesses and the Federal Government would be positive. As discussed in Section N1.2, there are previous studies that have demonstrated economic viability for nourishment in the study area, and other studies such as in the US support the economic benefits of beach nourishment (although it is recognised that the latter may be site specific).

For the considered but dismissed options, negative financial impacts were determined for numerous stakeholders, namely:

- negative impacts on Council, beachfront landowners, wider Warringah ratepayers and the NSW and Federal Government if beachfront landowners were not permitted to redevelop (and without any form of compensation), see Table N4;
- negative impacts on Council, wider Warringah ratepayers and the NSW and Federal Government if Council purchased beachfront property as it came on to the market, with only beachfront landowners seeing a positive impact (Table N5); and
- negative impacts on Council and wider Warringah ratepayers if Council funded upgrading and infilling of protective works south of Devitt Street at Collaroy-Narrabeen Beach (there would be positive impacts on beachfront landowners and the NSW and Federal Government[13]), see Table N6.

Therefore, the high level analysis herein generally supports the dismissal of the options considered in Section N3.

[13] The NSW and Federal Government would also see these positive impacts if landowners funded the protective works as per the proposed option in Table N2. Landowners were also found to experience positive impacts in Table N2, but they we would be less than if the Table N6 option was adopted.

Appendix O:
Sources of Funding for CZMP Actions

WARRINGAH COUNCIL

Royal HaskoningDHV
Enhancing Society Together

CONTENTS

O1. INTRODUCTION

Various potential Federal, NSW and Council funding sources for funding of CZMP actions are outlined in Section O2, O3 and O4 respectively.

Funding programs are regularly changing and Council would need to maintain an awareness of other funding opportunities as they arise.

O2. FEDERAL GOVERNMENT

Information in this Section was derived from Attorney-General's Department (2014).

During 2009, various Commonwealth programs for disaster mitigation works were replaced by the National Partnership Agreement on Natural Disaster Resilience (NPA). The NPA provides approximately $27 million per year to states and territories to enhance the resilience of communities against the impact of natural disasters. The NPA consolidates the former Bushfire Mitigation Program (BMP), the Natural Disaster Mitigation Program (NDMP) and the National Emergency Volunteer Support Fund (NEVSF).

A key aim of the NPA is to enhance Australia's resilience to natural disasters through mitigation works, measures and related activities that contribute to safer, sustainable communities better able to withstand the effects of disasters, particularly those arising from the impact of climate change.

The NPA is a partnership with states and territories where jurisdictions provide direct administration of the funding and submit an annual implementation plan to the Attorney-General.

Funding for projects is prioritised by states and territories in the context of their natural disaster risk priorities. This recognises that different jurisdictions have different priorities and that these may change over time. Each state and territory will ascertain eligibility for funding against their risk priorities when applications are called for.

NSW aspects of the program are described in O3.3.4.

O3. NSW GOVERNMENT

O3.1 NSW Coastal Management Program

Grants under the NSW Coastal Management Program are administered by the Office of Environment and Heritage (OEH) to support Councils in their management of coastal hazards. Up to 50% of project costs that can be funded include (OEH, 2014b):

- preparation (or updating) of coastal zone management plans and associated technical studies (including coastal hazard assessments);
- action to manage the risks from coastal hazards;
- action to implement environmental repairs, including habitat restoration and conservation projects;
- pre-construction activities for projects that are eligible and are likely to proceed to construction; and
- development of management tools (such as education projects).

OEH typically provides about $2 million per annum in the program. However, this funding level has stayed approximately the same in dollar terms for decades, so in real terms has been dropping.

O3.2 NSW Floodplain Management Program

Grants under the NSW Floodplain Management Program are also administered by OEH to support councils in their management of flood risk. Grants provided under the program typically comprise payment of $2 from OEH for every $1 provided by councils.

Funding under this program has previously been jointly secured by Pittwater and Warringah Councils for Narrabeen Lagoon entrance clearance works. These works are periodically undertaken for the primary purpose of flood mitigation around Narrabeen Lagoon but have a secondary benefit of returning sand lost from the active beach system to Collaroy-Narrabeen Beach.

O3.3 NSW Natural Disaster Assistance Schemes

O3.3.1 General

In the event of a severe natural disaster, Councils are able to apply for financial assistance from the NSW Government for emergency work and restoration of damaged public assets provided that certain criteria are met. Natural disasters can be caused by coastal hazards including storm, storm surge, cyclone and tsunami. This funding is only made available if a Natural Disaster Declaration has been issued by the NSW Premier, Treasurer or their delegate. A Natural Disaster Declaration is only considered if the damage to an affected community (including damage to public assets, and other eligible costs incurred by the local community) exceeds $240,000.

Separate grants can be issued by NSW Roads and Maritime Services (RMS) for damage to roads (Section O3.3.2) and NSW Public Works (Section O3.3.3) for restoration works other than those involving roads. In addition, grants are also available from the Natural Disaster Resilience Program (Section O3.3.4).

O3.3.2 NSW Roads and Maritime Services – Natural Disaster Arrangements

In the event of a declared natural disaster, the funding available from RMS for restoration of road infrastructure comprises:

- Emergency Works – 100% of the approved actual cost;
- State and Regional roads – 100% of the approved actual costs; and
- Local Roads – 75% of the assessed cost up to $116,000 and 100% thereafter.

For non-declared events, the responsibility for funding of restoration works is as follows:

- State Roads – RMS responsibility;
- Regional Roads – Council responsibility; and
- Local Roads – Council responsibility.

Coastal erosion during major storms may cause damage to road heads along Collaroy-Narrabeen Beach and Fishermans Beach, which are all classified as Local Roads.

O3.3.3 NSW Public Works – Natural Disaster Relief and Recovery Arrangements

In the event of a declared natural disaster, there are two broad categories of works for which NSW Public Works can provide financial assistance. These comprise:

- Emergency Works, for which 100% of costs can be subsidised; and
- Restoration Works, for which 75% of costs can be subsidised up to a maximum of $116,000, and 100% thereafter (the maximum amount payable by Councils for Restoration Works under this program is thus capped at $29,000 for any disaster event[1]).

Eligible items of work that are relevant for the study area under each of the above categories include:

- Emergency Works:
  - clean-up of debris from Council maintained areas; and
  - clearance of blockage and debris from public drainage.
- Restoration Works for:
  - stormwater assets;
  - tree replacement;
  - retaining walls and rock protection;
  - recreational facilities and play equipment; and
  - fencing.

Non-eligible items include the “restoration of damage that can be wholly or partly attributed to inadequate design, inadequate maintenance or faulty construction”. This is of interest for future restoration works that may be proposed for existing protective works located seaward of public assets such as road heads, surf clubs, etc., given that these protective works have generally not been certified nor maintained on a regular basis.

[1] Being 25% of $116,000.

Restoration of damage to beaches and dunes (such as by beach nourishment and/or revegetation of dunes) would not be funded. However, damage to Council beach access and dune protection infrastructure (such as fencing) is eligible for restoration funding.

O3.3.4 Natural Disaster Resilience Program

The Natural Disaster Resilience Program (NDRP) is the joint Commonwealth/State program funded under the two year National Partnership Agreement on Natural Disaster Resilience (NPA, see Section O2).

The funding available from the Natural Disaster Resilience Program (NDRP) supports a wide range of activities including research and development, disaster risk assessments, physical works and engineering measures, community education and engagement programs and projects that support emergency management volunteers. In NSW it is administered by the Ministry for Police and Emergency Services and has been used in the past to partly fund coastal management studies and plans for local government areas.

O4. COUNCIL REVENUE

O4.1.1 General

In addition to external grant funding, Council could fund coastal management actions from their own revenue generated by ordinary rate income, special rate variations or a coastal protection service charge. The potential use of revenue generated outside of ordinary rate income is discussed below.

O4.1.2 Council Wide Special Rate Variations

Councils are able to apply for increases in ordinary rate income beyond the annual rate peg amount (a 'special rate variation'). Councils may apply for a single year increase under Section 508(2) of the *Local Government Act 1993*, or a multi-year increase (of between 2 and 7 years) under Section 508A.

The Independent Pricing and Regulatory Tribunal (IPART) has the responsibility for assessing and determining special rate variation applications. Councils may seek a special rate variation in order to undertake environmental works, fund town improvements, redevelop community and civic facilities, address maintenance backlogs and maintain or improve existing service provision. Beach nourishment could be considered as an environmental work that benefits all beach users, with the main aim of providing a wider beach (or maintaining beach width under sea level rise) to enhance or maintain beach amenity.

Councils that are seeking special rate variations are required to submit applications to IPART for review and assessment. The Council must include details of its intention to apply for a special variation in its draft delivery program and operational plan and must consider any submissions received from the public. If a Council's application is approved, IPART will specify the percentage by which the council may increase its ordinary rate income. IPART must assess special variation applications against the following criteria: demonstrated need for the rate increase, demonstrated community support for the special variation, reasonable impact on ratepayers, sustainable financial strategy consistent with the principles of intergenerational equity, productivity improvements achieved and planned, and implementation of the Integrated Planning and Reporting framework.

O4.1.3 Special Rate on Particular Properties

Based on Section 495(1) of the *Local Government Act 1993*, a "council may make a special rate for or towards meeting the cost of any works, services, facilities or activities provided or undertaken, or proposed to be provided or undertaken, by the council within the whole or any part of the council's area, other than domestic waste management services".

Based on Section 495(2) of the *Local Government Act 1993*, "the special rate is to be levied on such rateable land in the council's area as, in the council's opinion: (a) benefits or will benefit from the works, services, facilities or activities, or (b) contributes or will contribute to the need for the works, services, facilities or activities, or (c) has or will have access to the works, services, facilities or activities"[2].

[2] There is also Section 529 of the *Local Government Act 1993* that says a Council may determine a sub-category or sub-categories for one or more categories of rateable land in its area, but this would not seemingly be for the case of rating coastal landowners differently.

Therefore, if Council changed its current position and chose to financially contribute to upgrading or providing new protective works adjacent to private property then a special rate on beachfront landowners (who would be the main beneficiaries of these works) could be considered to assist in funding these works.

O4.1.4 Coastal Protection Service Charge

It is also possible to levy particular coastal landowners by applying annual charges for coastal protection services. This is set out in Section 496B of the *Local Government Act 1993*, entitled "making and levying of annual charges for coastal protection services". Guidance on the application of the coastal protection service charge is also provided in the *Coastal Protection Service Charge Guidelines* (DECCW, 2010d).

There are three situations when the coastal protection service charge (CPSC) could apply, namely:

1. when landowners construct protective works and Council maintains them;
2. Council constructs protective works to protect private property and maintains them; or
3. Council maintains existing protective works on behalf of a landowner.

In all cases, Council could levy the landowner for maintaining and repairing the works and mitigating any impacts (such as replacement of eroded beach sand). In Item 2, the CPSC cannot be used to fund the initial new or upgrading works

However, Council has stated that it does not intend to protect private property from coastal erosion (so Item 2 above is not relevant). Furthermore, Council does not intend to maintain existing or any new/upgraded protective works adjacent to private property, considering that this is the landowners responsibility (so Item 1 and 3 above are not relevant).

Based on Section 553B(1) of the *Local Government Act 1993* "an annual charge for coastal protection services may not be levied on a parcel of rateable land in relation to existing coastal protection works unless the owner (or any previous owner) of that land has consented in writing to the land being subject to such charges". That is, the CPSC can only be applied if a landowner agrees to it.

To reiterate, the CPSC cannot be used to fund construction of new works or upgrade works, only maintenance and repair of existing protection works that have been voluntarily constructed or financially contributed to by a benefiting landowner (or landowners) or where a landowner has agreed to pay a CPSC for maintenance and repair of existing protection works that they did not financially contribute to.

A coastal protection service charge may have potential application in situations where consent for future development has been granted subject to upgrade and maintenance of an existing seawall or construction and maintenance of a new seawall. If agreed with the landowner, conditions of this consent could include payment to Council of a CPSC associated with Council's maintenance of the seawall on behalf of the landowner to provide greater certainty that satisfactory arrangements have been made for ongoing maintenance of the seawall works in accordance with Section 55M of the *Coastal Protection Act 1979*.

However, Council does not have to provide this maintenance service and does not intend to enter into these types of arrangements. Council's position is that it is the landowner's responsibility to maintain and repair any protective works that the landowner has constructed or upgraded to protect private property (or that were pre-existing prior to their purchase) and that Council's resources should only be used for protection of public assets.

Appendix Q: References

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